REPORT

OF THE

GEOLOGICAL SURVEY

OF

NORTH DAKOTA

1900

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First Biennial Report

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STATE GEOLOGIST

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ADDRESS.

STATE UNIVERSITY OF NORTH DAKOTA,
January 24, 1901.

HON. DAVID BARTLETT,

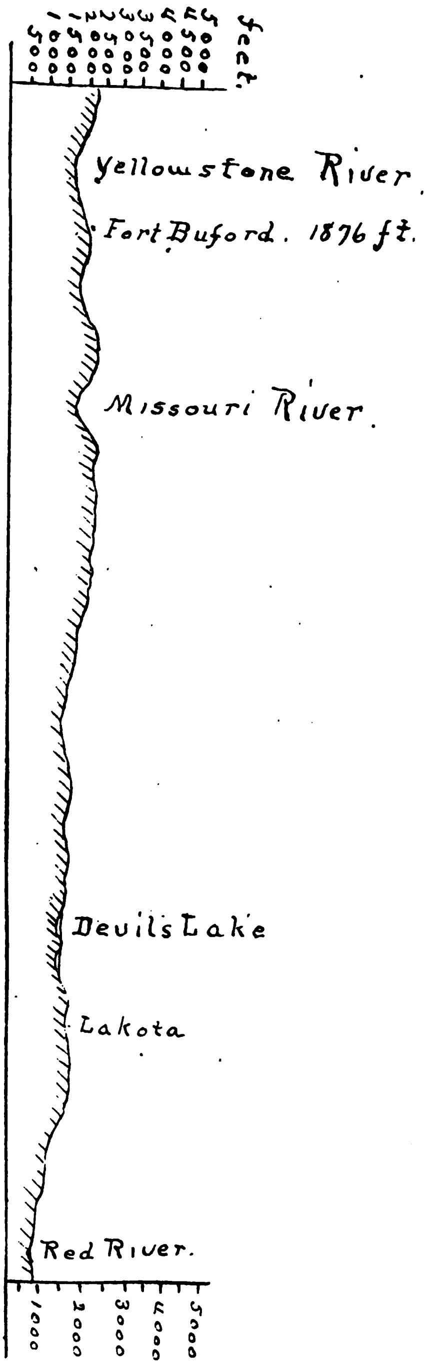
President of the Board of Trustees of the State University of North Dakota:

DEAR SIR: I have the honor to present herewith the first biennial report of the progress on the geological survey of this state.

Recognizing the vast importance of the mining industry, in some form or other, most of the states of the union have established geological surveys. The geological and natural history survey of North Dakota was established at the University in connection with the School of Mines, and by that act the professor of geology was made state geologist, an arrangement generally adopted by various states. However, no appropriation to begin the work was made until two years ago. Prior to that time the writer of this report had devoted most of his summer vacations for eight years to geological investigations of the state and in efforts to encourage the development of the mineral resources. Two short bulletins were issued, embodying a preliminary report of some of these investigations. During six years of this time the state paid nothing for the work, the expenses were borne by the writer, and his time during these vacations was cheerfully contributed for the good of the cause. Thus a large amount of materials and data was collected absolutely without expense to the state. Had it not been for this fact it would have been impossible, with the allowance of only $300 per year for expenses, to have done the field work and carried on the investigations shown in this report.

The last legislature recognized that the time had come when the interests of the state demanded that the work be begun. It therefore made a small appropriation, simply enough to organize and commence the work of a geological survey of the state. The survey has been begun and we believe that the work will very soon fully show its utility and economic value to the whole state.

Something is known of the vast deposits of lignite coal, but it is surprising how little the immense value of these deposits is appreciated. The region possessing these deposits should be helped to a thorough scientific survey, and investigations should be carried on for the purpose of discovering and making known the best and most economical methods of burning these coals. The geologist



PROFILE OF NORTH DAKOTA NEAR THE 48TH PARALLEL.

has been over most of the coal regions during the past summer and work of this kind has now been begun. The preliminary results will be published in this report. A brief account will be given of some of the beds of rare and very valuable clays found in the state. There is no reason why in time large industries cannot be built upon these resources.

An important geological study is that of the water supply of the state. During the past two years a study of this problem has been pretty well started by the state geologist, and the results of this work, which has been carried on in connection with the United States Geological Survey, will be included in this report. Several hundred samples of water from different sources and from various parts of the state have been examined and a study of the geological conditions made for the purpose of pointing out the best methods of regulating the supplies and uses and for improving the character of the water in many regions. Too much importance cannot be attached to such work, since the health, happiness and prosperity of a community depend to a large degree upon the water supply.

The writer wishes it clearly understood that this is in no sense a finished report, but rather only a preliminary bulletin. It has been hurriedly prepared under pressure of other work and during the short interval which could be gotten after the completion of the daily duties which devolve upon him as professor of chemistry and geology at the University of North Dakota. It is hoped that these conditions will not be overlooked in considering any faults which may appear in this report.

The United States Geological Survey has kindly permitted the use, in advance, of considerable data from a bulletin which the writer is preparing on the water resources of North Dakota, and which will soon be published by the United States Geological Survey. In the preparation of this report much aid has been rendered in the analyses of specimens and in other work by Miss Marcia Bisbee, Instructor in Chemistry at the University. Credit is also due to Miss Edith Johnson for excellent service rendered the survey.

It has been the desire of the geologist in charge of this work to make a thorough and systematic geological and mineral survey of the entire state, to publish from time to time the results of these investigations, and to assist in every way possible in developing the natural resources of the commonwealth. Such a survey is provided for in most of the states and has proved itself of great value. It will be especially important in a new state like North Dakota, for it will show the existence and value of resources which would otherwise remain unknown. Those who think North Dakota devoid of all mineral resources have a mistaken notion. The idea comes from the fact that up to this time there has been made almost no thorough scientific research to reveal these resources. While our state may never appear as a great mining state, yet it possesses some mineral deposits which are almost certain to become extensively used.

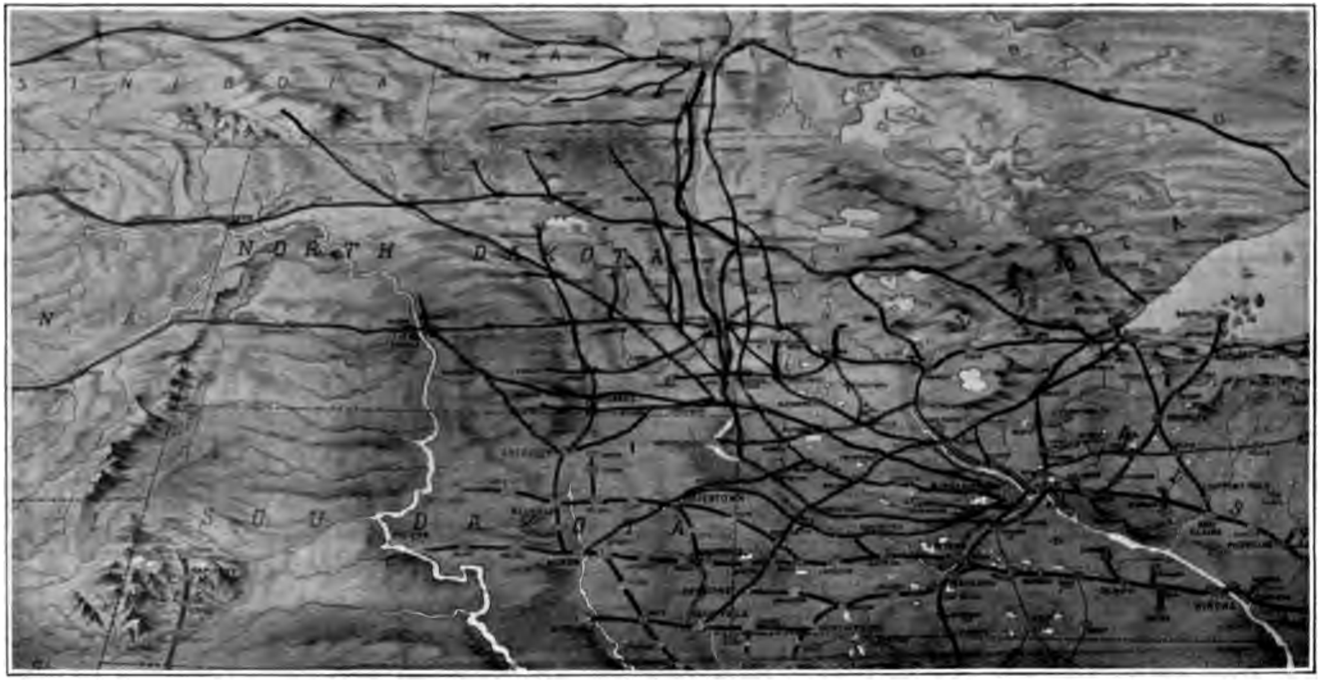
The ultimate value of the mineral resources of this state is made evident when we consider the growth which has taken place during the last ten years in the industries covered by this report. As nearly as can be estimated the capital invested ten years ago, principally in the coal and clay industries, amounted to about $75,000; today it probably amounts to from $275,000 to $325,000. Ten years ago the total annual value of the products of this character was about $40,000; now it will probably reach from $285,000 to $345,000. As most of this growth has taken place in the last five years it does not seem unreasonable to expect a corresponding growth during the next decade, at the end of which time our mineral industries will represent an invested capital and productive power of no mean proportions. It will thus be seen that it is now well worth expending our efforts in encouraging the development of our mineral resources.

The building up of a geological and topographical map of the state has already been begun. This report of the geological survey of the state embraces the topography and general geology of North Dakota, studies on the water supply, clays and coals. It is hoped that the result of the investigations which have been carried on during the past two years, as embodied in this report of the survey, will many times repay the trifling expense it has caused the state. Every dollar expended on a geological survey will doubtless bring back to the state several hundred fold. The enormous profits derived by the older states from expenditures on such a geological survey is unquestionable. North Dakota should in time secure equal benefits from the prosecution of the survey now begun.

Respectfully,

E. J. BABCOCK,

State Geologist and Professor of Chemistry and Geology.



A RELIEF MAP OF NORTH DAKOTA.

TOPOGRAPHY.

In common with most of the great prairie districts west of the Mississippi river, North Dakota presents no great extremes of altitude and no very marked features of topography. Like a large part of the Great Plains it is principally characterized by the vast expanse of nearly level or rolling prairies. In the main the land is well supplied with surface water by several river systems and numerous small lakes. The four most important rivers are the Red River of the North, along the eastern boundary of the state, the Missouri river in the western part, and the Sheyenne and James rivers in the central portion of the state. Nearly all the streams within the limits of North Dakota are sluggish, rather shallow, and often muddy. As might be expected from the geology, they lack the falls and cataracts and the sparkling character of the streams of a more rugged and rocky country.

The state, however, is not without a modest variety of surface, for there is not only the very level plain of the valley of the Red River of the North and districts west and southwest, but there is much beautifully rolling prairie, especially between the Pembina and Turtle mountains on the north and the Sheyenne river on the south. Along the Souris and Missouri rivers toward the northwest are undulating plateaus, and in the southwestern portion of the state are the more extensively eroded surfaces which, in some localities, present in miniature the wildness and picturesqueness of the Grand Canyon district of the Colorado. While no very marked natural divisions can be traced, the surface may in a general way be classified topographically as follows: Red River valley, Pembina and Turtle Mountain highlands, central rolling prairie, and the western coteau of the Missouri.

The Red River Valley.—The Red River valley lies along the eastern boundary of North Dakota and comprises a tract from 25 to 70 miles wide, extending across the state from south to north. This whole area is very nearly a level plain, rising slightly on both sides of the stream which gives its name. The river flows somewhat east of the central portion of this flat bottom in a general course from south to north. Its channel is winding as is common to streams flowing slowly through clay and other easily eroded material. The banks of the stream, which are mostly of fine silt and clay, rise rapidly on both sides to from 15 to 45 feet above the water. Most of the tributaries are small and cross the plains in similar channels which frequently widen out in spring into little ponds that nearly always become dry by early summer. The drainage is gotten principally by these tributary gullies, which, though small, are of great

advantage in carrying the spring floods and, later in the season, in furnishing good pasture land.

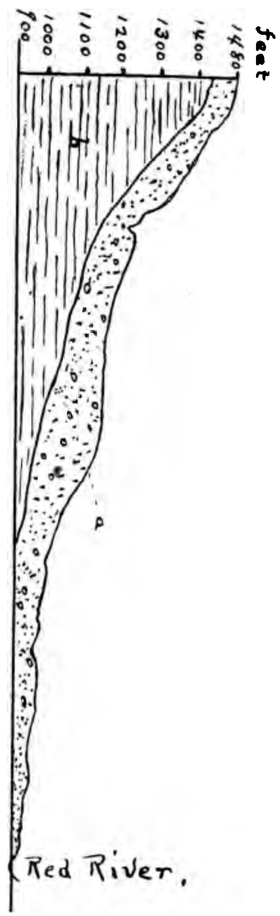
The valley has a very uniform descent toward the north, but so slight as to be entirely imperceptible to the eye. The inclination usually ranges from about 6 inches to 2 feet to the mile. At Wahpeton the surface is about 960 feet above sea level; near Fargo about 900 feet; near Grand Forks about 830 feet; and at the international boundary about 790 feet. Toward the west the ascent from the river is somewhat more rapid, averaging from 50 to 75 feet to the mile for the first 25 miles. Near the boundary line a distance of 30 miles west of the river brings one to the edge of the valley at the Pembina mountains, which rise from 300 to 350 feet above the surface. West of the river from 25 to 50 miles the ascent becomes quite rapid as the various ridges of glacial deposits are passed, until, going beyond the Red River valley the central portion of the state is reached.

The Red River valley is immediately underlain by alluvial clays, modified drift, sand and gravel. With this remarkably strong subsoil and equally remarkable deep and rich upper soil there is good reason for the fertility which has characterized this region. A large variety of prairie grasses grow with great luxuriance in this valley, but it is especially noted for its large yields of a superior quality of wheat. There is considerable timber skirting the banks of the Red river but very little away from the stream.

Pembina Mountains.—Going west about 30 miles from the Red River of the North near the international boundary, one reaches an area rising abruptly from the gentle inclination of the valley to a height from 400 to 600 feet above the Red river. This elevated land stretches many miles northward into Canada, and southward forms a gradually descending plain far into the central part of the state. In its northeastern portion this elevated tract is known as the Pembina Mountains. Toward the west the elevation increases slightly, occasionally interrupted by low land, until it practically units with the Turtle Mountain highland west of the Pembina mountains. Topographically, as well as geologically, these two elevations should be considered together.

Along the northern part of the eastern slope of the Pembina mountains the elevation presents the appearance of a prominent wooded bluff rising from 250 to 350 feet above the surrounding level and extending in a nearly direct line toward the south. This ridge gradually decreases in elevation until at its southeastern extremity it is scarcely more than 50 feet above the country around, and then it is lost in the rolling prairie. Along the eastern edge of the escarpment the elevation above the sea ranges from about 1,100 feet in the eastern part to 1,500 or 1,550 feet in the northwestern.

The eastern face of this escarpment is frequently scarred by deep transverse ravines running back from the edge of the hills from one to 15 miles toward the west. Nearly all of these valleys are covered



Scale about nine miles to an inch.
From Red River west, showing formation of Pembina Mts. near international boundary
a: silt and till.
b: cretaceous shale.

with small timber, and in the spring contain small steams which in most cases become nearly dry in summer. Along the sides of these gullies are numerous springs of good water (usually slightly impregnated with sulphur and lime). In summer these springs become the main supplies which keep up the brooks. There are only three of four streams worthy of mention along the eastern slope of the Pembina mountains. In the northern part the Little Pembina has cut a channel through the drift and clay from 50 to 350 feet in depth. This stream flows about 10 miles east and from 4 to 6 miles north into the Big Pembina river near the international boundary line. For most of its way the stream occupies a very narrow winding bed in a valley from one-quarter to one-half mile wide and usually 300 feet or more deep. The stream is fed for a large part of the year by numerous springs. The ravine through which it passes

is well supplied with small timber (cottonwood, poplar and oak). There are many charming views along this stream.

A few miles south of the Little Pembina river is the Tongue river, which presents general characteristics much like the Little Pembina but which flows a much shorter distance through the Pembina highland. Ten or twelve miles south of the Tongue river is the north branch of the Park river. The three branches of the Park flow through the descending southern portion of this elevation and, as would be expected, have shallower and narrower banks and much slower currents. The banks have but few trees.

The most important stream of this region is the Pembina river, which flows through the mountains near the international boundary line. This river rises far to the west near the Turtle mountains and flows in an easterly direction through Manitoba and North Dakota into the Red river near the town of Pembina. In a direct line this distance is probably 120 miles or more, but by the actual length of the stream it is much greater, since its course is quite circuitous. A large portion of its channel has been cut through the Turtle and Pembina Mountain highland. Its banks are from 50 to 350 feet high and the valley varies in width from a few rods to nearly a mile. Along the deepest part of the valley, toward the eastern part of the Pembina mountains, the banks are high and rugged and well covered with small trees. At Walhalla the river flows out of the higher part of this elevation through a low ridge of drift and clay into the Red River valley. From Walhalla back several miles to what is known as the "Fish Trap" the river has a very rapid current. At the latter place there is a good water power, and at Walhalla a small part of the power is used to run two or three mills. From its source to Walhalla the river falls about 700 feet and from Walhalla to the mouth about 185 feet.

The Turtle Mountians.—From the ravines of the streams along the eastern edge, the crest of the Pembina mountains forms a treeless, rolling plateau stretching away toward the west. Over most of this tract between the Pembina and the Turtle Mounains, a distance of about 100 miles, there is very little to note except that it is a high prairie. There are but few streams and lakes or other marked surface features. On the eastern and western extremes usually good crops of small grains are raised, but the central portion is at present largely used for grazing. This section is well supplied with a variety of excellent prairie grasses. Toward the western edge of this belt there is a gradual elevation approaching the Turtle mountains, and a slight descent toward the south. The southern slope shows a very gentle drainage system beginning near the base of the Turtle mountains and becoming more pronounced as it extends farther into the Devils Lake basin. In fact, this basin is the natural drainage reservoir for the waters of the larger part of the northern highland just discussed. There are no streams worthy of mention along the western part of this district except those which, like the Pembina river, have their sources on the northern side of the Turtle

PEMBINA RIVER. PEMBINA MOUNTAINS—(NEAR WALHALLA, N. D.)

mountains in Canada. Yet while there is no river drainage to the south worth mentioning there is certainly a great southern surface and sub-surface drainage. Doubtless much water slowly percolates through the drift and upon and in the Cretaceous clays from this elevation toward the basin in which Devils Lake is situated.

The Turtle mountains proper form a high, rolling plateau about 40 miles long by 30 miles wide, its longer axis being east and west. The surface rises gradually from all sides, but within one or two miles the elevation suddenly increases until it reaches a height of 300 to 400 feet above the surrounding country. The sides of the hills are nearly treeless, but among the hilltops there is a good deal of small timber. The Turtle mountains present a very broken outline on account of the large number of subordinate hills and ridges. The highest of the buttes reach an elevation of 2,500 feet above the sea, or 600 feet above the surrounding country. The top of the mountains has a beautifully rolling surface covered with trees and dotted with lakes and ponds. Many fine farms are located here. Near the central part of these hills is the attractive little lake Metigoshe. Springs and spring brooks are common along the hillsides. North of Dunseith and also north of Bottineau are several large springs. About two miles north of Bottineau a tract of several acres along a hillside seems to consist of one vast spring. Located as this great spring is 300 feet or more above the town it seems wonderfully well situated to furnish a water supply for domestic purposes and for power. The water which oozes out of this hillside is rather highly charged with lime, but otherwise seems to be of excellent character.

The Turtle mountains consist of a mass of Cretaceous and Laramie slates and clays which have escaped erosion and are covered with a thin layer of drift material. This material is, however, somewhat cut out on top of the plateau and thus is formed a great gathering reservior. No doubt a large amount of the water flowing in the brooks and from the numerous springs has gradually seeped through the clays and sand to the hillsides where it emerges as springs. The Turtle Mountain district certainly is to a greater or less degree connected with the underground water supply of the prairies to the south.

The Devils Lake Region.—Looking toward the south from the heights of the Turtle mountains one has spread out 400 feet or more below him a beautiful view of a gently rolling prairie region dotted with small farm houses surrounded occasionally by planted groves. As far as the eye can reach this undulating surface extends, graudually decreasing in elevation as it approaches Devils Lake. From points farther east, toward the Pembina mountains, a similar though less marked descent toward the south is noticeable. So, as has been said, the Devils Lake region becomes the natural gathering basin for this northern highland district. This basin has flowing into it only small streams, for the most part coulees which often become dry in the summer. There are very many of these shallow water

courses now mostly dry which were doubtless at one time very important factors in draining the northern district and in maintaining the supply of surface water in and about Devils Lake. When the land was thickly covered with prairie grass the latter apparently served as a thatch which prevented the water from soaking into the soil. This of course allowed more water to accumulate in the coulees and eventually in the lake basin. As the land was put under the plow more of the water which fell as rain percolated through the soil and a smaller proportion ran away as surface water. Thus there seems to be good reason for the noticeable decrease in the quantity of water in the lakes and ponds of this region.

Many of the coulees originate in the Turtle mountains and flow in general toward the south, but their course is generally very winding. They vary in size from wide sags only two or three feet deep to narrow channels 50 to 100 feet wide and with banks 25 feet high. When water is not flowing through them small ponds are frequently left. The wider portions usually make valuable hay and pasture lands.

In the northern and northeastern part of this region the streams cut through a rich and rather clayey soil and a strong blue clay subsoil which is largely mixed with drift material. Toward the west from Cando to Rugby and for some distance west and south of Rugby the surface is somewhat more rolling and the soil has a larger proportion of sand. The natural drainage of this region is toward the southeast, and from Rugby there is a well-marked drainage to the Sheyenne and James rivers. This old tributary to these rivers is now usually dry. There are, however, a few ponds and lakes left, notable among which is Girard lake, a body of water perhaps three miles long and from one mile to two miles wide.

Girard lake and several smaller lakes which were evidently at one time parts of it, show in many places, by their marked shore lines and deposits, a period when the water was from 10 to 30 or 40 feet higher and spread over an area several times as great as that now occupied. This old lake had a very irregular shore line; its length was probably greatest from northwest to southeast. In many places now several feet above the water level are two or three lines of boulders and gravel and occasional stumps of silicified wood. There is no doubt that this lake had its outlet to the Sheyenne river and the upper feeders of the James river. That these conditions remained nearly constant for some time is evident from the character of the old shore deposits as well as from the banks of the upper Sheyenne river.

By far the most characteristic feature of this part of the state is Devils Lake and the surrounding country. This lake lies along Ramsey and Benson counties with its length extending east and west. Taking the lake with its arms, some of which are nearly dry or separated by portions of land but which properly belong to the lake at its present stage, the length would be about 24 miles and the width averages perhaps between 4 and 7 miles. There

was unquestionably a time, early in the history of the lake, when it occupied two or three times its present area. The old shore lines indicate that its water level must have been from 20 to 40 feet above that of today. Now the water is 25 to 30 feet deep, away from the shore, as indicated by a number of soundings. The southern shore of the lake, which is often thickly strewn with large boulders, rises rather rapidly into a high rolling country whose surface is broken by numerous steep knobs, some of them 200 to 275 feet above the water level. The western part of this tract is included in the Sioux Indian reservation. The northern, western and eastern shores rise gradually from the water's edge for several miles back from the lake. The old lake extended much farther north and west, as may well be seen by the old bays which are now dry or are only moist enough for good meadows. The lake is now fed by the immediate surface drainage which is usually carried by a few coulees. A large part of the water which formerly drained into the lake from a distance has been cut off by the cultivation of the prairie land. As a result the shallower parts of the lake have, within the last 15 years, dried up and the water area has thus been very much reduced. It does not seem probable that a proportional decrease will follow within the next 15 years.

The central portion of the state south of Devils Lake is drained by the Sheyenne and James rivers. The Sheyenne rises about 30 miles west of Devils Lake and flows in a very winding channel for about 90 miles toward the east; then it takes a course nearly due south for about 100 miles until, 20 miles or so from the southeastern limit of the state, it turns northeasterly into the Red River valley and empties into the Red river a short distance above Fargo. For the greater part of its course the stream is narrow, its channel being cut through yellow and blue clays. Often the banks are strewn high up on the sides with glacial debris. They vary greatly in height, from a few feet near the mouth to 80 or 90 feet near the upper waters. Along parts of the river course there are well marked terraces which were doubtless formed when the stream was an outlet for the glacial lake region to the north. The western part of the country drained by the Sheyenne river is a high, rolling prairie, often from 1,300 to 1,600 feet above the sea. The soil is very rich and, when there is a fair amount of rainfall, produces an abundant crop.

Some of the small steams which form the headwaters of the James river are southwest of Devils Lake and within a few miles of the source of the Sheyenne. At this place the two rivers are separated by a ridge several miles wide. The country around the western tributaries of this river is much the same as that about the Sheyenne river. The two rivers doubtless joined in the work of draining the early glacial lakes. The James river flows for about 150 miles in a southeasterly direction until it crosses the state line into South Dakota. The general character of the stream and of the surrounding country is much the same as that of the Sheyenne

river. The surface to the south is rather more level and of much lower altitude. The channel is cut through clay and drift, but the soil and subsoil have a larger proportion of sand than is found farther north.

Western North Dakota.—Western North Dakota is watered principally by the Missouri, Cannon Ball, Heart, Knife and Little Missouri rivers and a number of smaller streams which directly or indirectly flow into the Missouri. The streams cut through upper Cretaceous clays and sands and in the western part through Laramie foımations. The land is high and rolling, increasing in elevation toward the west and northwest. The general drainage shows very clearly in passing from the Little Missouri east to the Missouri, for the eastern border of the Missouri river is much lower and shows that it has been gradually cut away from the higher western district. While the altitude about the Little Missouri is much greater than that of the Missouri, still there has been very extensive erosion in that section known as the Bad Lands where the streams lie from 2,000 to 2,300 feet above sea level. From a geological standpoint this is one of the most interesting parts of the state.

FARM SCENE ON MISSOURI RIVER.

A TABLE OF ALTITUDES

(A few locations in North Dakota.)

	Feet Above Sea Level.
Bathgate	821
Bismarck	1,677
Bottineau	1,644
Burlington	1,585
Butte St. Paul, Turtle Mountains.. .. ..(about)	2,300
Cando	1,490
Carrington	1,584
Churchs Ferry	1,461
Cooperstown	1,428
Coteau de Missouri	2,400
Devils Lake	1,467
Dickinson	2,403
Fargo	903
Fessenden	1,607
Ft. Berthold	1,873
Grafton	824
Grand Forks	826
Grand Harbor	1,460
Harvey	1,596
Hillsboro	901
James River bed, N. P. crossing	1,499
Jamestown	1,408
Kenmare	1,792
Lakota	1,514
LaMoure	1,403
Langdon	1,610
Larimore	1,134
Leeds	1,519
Lisbon	1,091
Little Missouri	2,255
Mandan	1,644
Milton	1,586
Minnewaukan	1,461
Minot	1,558
Park River	998
Pembina	753
Portal	1,952
Rugby	1,567
Sims	1,960
Sheyenne River bed, N. P. crossing	1,409
Steele	1,857
St. Johns	1,950
Valley City	1,227
Velva	1,516
Wahpeton	965
Willow City	1,478

Many of these elevations were taken at railroad levels at the respective places.

GEOLOGY.

North Dakota is remarkable for its lack of diversity in geologic formations, especially such as appear at or near the surface. This fact has not been conducive to interest in geologic studies in this state. It has also made it exceedingly difficult to locate within narrow limits any formations excepting those most apparent. Therefore it will require many years for careful observation and the gradual accumulation of data regarding the extent, depth and local characteristics of those formations which are covered by the thick deposits of the later Cretaceous, Tertiary or drift material. The uniformly level character of the land and the lack of uplifts or deep erosion over most of the state have given very few outcrops by which to study the geology. Most of the information we have of all but the surface formations has been obtained from deep well borings. The difficulty experienced in securing such information does not render it wholly reliable, so whatever is said of the extent, depth, etc., of the lower formations must be considered as approximations only. This is true not only of the lower formations but of portions of the upper beds, since many parts of the state have not been studied by geologists; indeed, only a small area has been given any very careful examination.

So far as is at present known, the geological formations found in North Dakota may be summarized as follows: Archean, Silurian, Cretaceous (including the Dakota, Benton, Niobrara, Pierre and Fox Hills, and Laramie), Tertiary, Glacial drift and Alluvial deposits. Our knowledge of the Archean and Silurian is confined to the eastern portion of the state. The Cretaceous overlies the older deposits and extends westward over a great part of the state. It varies in thickness from a few feet of Cretaceous debris to 1,000 or more feet. The various deposits belonging to this age are by far the most characteristic and important of any in the state. Deposits of the Laramie transition period and of the Tertiary are found in the western part of the state, mostly beyond the Missouri river, and are characterized by extensive beds of lignite coal and valuable fire clay and potter's clay. In the Bad Lands the Tertiary frequently appears in the higher buttes which mark the old Tertiary level.

Archean.—While no outcrops of the Archean appear, a great number of deep well drillings along the eastern portion of the state have reached this formation. In fact, the Red River valley is doubtless underlain by rocks of this age, evidently an extension of the great Archean belt found in northern Minnesota and southern Canada. The formation is characterized here as in general by granite, gneiss and schists. Near Big Stone lake, which really connects with the

Red river at the south, there are outcrops of granite. Northeast of this point granite has been reached by wells below from 50 to 125 feet of till. At some places, at least, magnesian limestone caps the granite. At Moorhead granite was reached at about 365 feet under a cover of layers of sand, blue shale, and glacial and alluvial debris. At Grand Forks, 80 miles farther north, granite or gneiss was reached at 385 ft. covered with a thin layer of Silurian limestone and layers of gravel, sand and clay. Immediately above the granite or gneiss was a deposit of granitic sand and gravel. The final borings which were taken from 15 feet in the solid rock showed a predominating pink feldspar and a composition characteristic of light gneiss or granite. About 45 miles farther north at Grafton, Archean rock was reached at 903 feet. Continuing farther north across the boundary, the Archean is found near the mouth of the Red river and to the northwest of Lake Winnipeg. How deeply it is covered to the west of the Red River valley cannot be said, but on account of the rapid accumulation of later deposits it would doubtless be rather deep. The old Archean floor on which the deposits in the Red River valley and those to the west lie was evidently rolling and probably eroded, as indicated by the character of the superincumbent sand and gravel found in some well borings.

Cambrian.—From records of the artesian well at Grafton, N. D., the Archean is there apparently overlain by Cambrian sandstone. It has been estimated that the total thickness of the Cambrian in this well is over 280 feet. If the records and identifications are correct there would seem to be a very marked undulation in the old Archean floor, which would lead us to expect a considerable area in the northeastern part of the state in which the Archean is overlain by Cambrian. However, we have now no evidence to prove this. Further north, about Lake Winnipeg in Canada, the Silurian is exposed, lying on the Archean with no intervening Cambrian. The Cambrian of the Grafton well therefore probably occupies a depression in the Archean floor.

Silurian.—As has already been intimated there is a deposit of Silurian rock within a portion of the Red River valley, under the thick deposit of glacial debris. Probably this formation is not found far to the western portion of the valley, but it doubtless extends, more or less continuously, beyond the northern boundary of the state, for outcrops are found about Lake Winnipeg in Canada. In the northern part of the state fragments of characteristic fossiliferous lower Silurian limestone are very common in the drift. It would seem that the southwestern limit of the Silurian in this valley is probably not far from Grand Forks, for a layer apparently of Silurian limestone of about one foot in thickness was found in a well at about 380 feet below the surface. This thin deposit indicates nearness to the limit of deposition in the old Silurian basin. This basin must have deepened rapidly, however, toward the north, for at the well in Grafton the total thickness of the Silurian is recorded as

about 317 feet including 137 feet of Galena and Trenton limestones, 93 feet of St. Peter sand and sandstone, and about 87 feet of lower Magnesian shales. This deposit increases in thickness toward the north and probably toward the west. At Rosenfield, in Canada, about 60 miles north of Grafton, the Silurian is said to reach a thickness of 892 feet. Thus it appears that the old Silurian sea or arm of the sea extended far to the north and deepened in that direction.

Toward the west its extent is uncertain. Where outcrops occur across the boundary line, the Silurian rocks lie in a nearly horizontal position upon the Archean. From the large proportion of Silurian rock material found in the gravel, sand and clay of the drifts of the Red River valley and the glacial deposits further west one might predict with a good deal of certainty the occurrence of outcrops of this limestone to the north. Large glacial boulders of limestone are not common, but the gravel and clay in the northeastern part of the state frequently contain as much limestone as granite and gneiss, a fact which has no small effect upon the fertility of the soil of this region.

Cretaceous.—Between the Silurian and the Cretaceous are several important geologic formations which have not been discovered within this state. From this it would appear that over a large portion of this state and much of Minnesota the Archean and Silurian formed for a long period the sea bottom and shore upon which the later Cretaceous waters spread their sediments. If other formations are present between the Silurian and the Cretaceous in this region they are very deeply covered with the Cretaceous and later material.

The Cretaceous of North Dakota is rendered worthy of more than a passing mention by reason of its great extent and thickness, its influence upon the soil and its connection with the artesian and shallow well water supplies. The Cretaceous formation found so extensively in North Dakota is only a part of a great belt extending from the Gulf of Mexico northwestward toward the Arctic regions and occupying a large part of the great western plains. Of course much of this is covered by the Tertiary deposits. The area of the Cretaceous just pointed out indicates the limits of an extensive inland sea which practically divided the continent into an eastern and a western strip. Between these the Central Plains formed a great basin which held the waters of this sea.

The Cretaceous period was doubtless both introduced and closed by some extensive variations in the elevations of the surrounding land surfaces; but during the greater part of this long period there seems to have been no very active change in this portion of the continent. Therefore, as might be expected, the deposits along the deeper parts of the sea show great similarity in character, whether found in North Dakota or farther south. The outlying shores, however, show considerable variation in different sections, depending largely upon the difference in the depth of water in which they were deposited and the character of the rocks which formed the shore in

various places. Most of the sediment deposited at that time was fine sand or clay which usually formed a muddy oozs often well mixed with lime alternated with deposits of fine sand. This material was washed from the shores by waves and brought from the neighboring lands by rivers, and was carried by currents and spread over the sea bottom as soft sediment. The shore line and sea level were changed from time to time and with them the size and erosive power of rivers and the direction and character of the sea currents, causing a corresponding variation in the deposits. Thus the Cretaceous is made up of a series of layers placed nearly horizontally one upon the other, and usually extending over hundreds of miles in area but varying much in thickness. By subsequent pressure and chemical changes brought about through a long period, these deposits were converted into more or less firm rocks, the mud forming shale and the sand forming sandstane.

The formations of the Cretaceous which are well represented in the Great Plains region have been classified as follows:

Laramie, transition between Cretaceous and Tertiary,

$$\text{Cretaceous}\left\{\begin{array}{l}\text{Fox Hills.}\\\text{Pierre.}\\\text{Niobrara.}\\\text{Benton.}\\\text{Dakota.}\end{array}\right.$$

All of these subdivisions are found within the limits of North Dakota, but not all are found throughout the state, some occurring only in a few localities. In certain sections some of the groups are very thin, while in others they are very thick, ranging from a few feet to several hundred. The series is probably best developed in the central portion of the state. In the eastern part the upper group is not found while the middle and lower groups (especially the Pierre and Dakota) are not difficult to reach in well borings. In the western and northwestern parts of the state the upper groups appear commonly and are doubtless underlain by the earlier formations.

The Dakota.—This group is, over a greater part of its extent, a sand deposit which has become more or less hardened and is often known as the Dakota sandstone. In this respect it is quite different from the upper groups, which are mostly clays. No surface exposures of the Dakota are found in North Dakota, but its relative position and, in a limited way, its extent, have been observed from the borings of many artesian wells in various parts of the state. From the records at hand it appears to underlie the upper Cretaceous and drift over practically the whole state, from the Red River valley on the east to the western limit, and from the Canadian line into South Dakota. The information regarding the thickness of this group is too meagre to warrant an estimate. From records the Dakota appears to be very thin in the eastern portion of the state, but it rapidly increases in thickness toward the central and western parts. This great deposit extends from the Canadian line through

North and South Dakota. The width varies greatly, but in this respect there is not so marked a variation as in the thickness, which over most of its expanse is quite uneven but in North Dakota usually thickens toward the west. It appears to have a general ascent toward the Rocky Mountain highlands, as in the Black Hills of South Dakota and along the mountains it is exposed at the surface.

The surface exposures of the Dakota sandstone, which along the Rocky Mountains aggregate many thousands of miles, are generally considered the gathering ground for the artesian wells. The lack of uniformity in thickness over large areas, which is so characteristic of this sandstone, indicates that at this period the sea and its arms varied much in depth, that the shore line often changed, and that the amount of sediment carried by streams into the sea was equally variable. Thus from the shifting to and fro of shore lines and ocean currents, the distribution of sand and clays on the old sea bottom became very uneven, especially near the limits of the area. The local variation in pressure and flow of artesian wells the writer believes to be largely due to this lack of uniformity in thickness of the sand deposits.

The Dakota sandstone through most of North and South Dakota contains a large proportion of fine quartz and mica often mixed with more or less clay and usually rather strongly saturated with sodium chloride and other mineral salts. Fossils are seldom found, but lignite fragments, iron pyrites and calcium sulphate nodules occasionally accompany the sand from wells. The material composing the Dakota formation was doubtless derived from the rock of the surrounding country, from the Archean and Silurian to the east and north and from these and other formations in the Rocky Mountain highlands, against which the waves were washing and over which the rivers were running, cutting and carrying away rock refuse. Evidence of this is afforded by the fact that there is in many places a similarity in composition between the Dakota sandstone and the immediately underlying formations. Especially is this noticeable along the eastern part of North and South Dakota where the Dakota sandstone lies just above the Archean or Archean and Silurian.

Benton and Niobrara.—The Benton, Niobrara and Pierre groups are often considered together on account of their great similarity and their close connection in local deposits. For convenience in this discussion we shall take only the Benton and Niobrara together. These groups immediately overlie the Dakota sandstone over a large part of that great section of the plains in which the later deposit occurs.

In North Dakota the Benton and Niobrara formations are well developed in the central and northern part of the state but seldom appear along the eastern border. They are readily distinguished from the Dakota by being principally composed of blue clays and shales and are generally of very fine material. Sand is occasionally present in these deposits but not to any great extent. The Niobrara and adjoining sections of the Benton are often rather strongly im-

pregnated with carbonate of lime, and in a few places in South Dakota they become quite pure chalk. The Benton rests directly upon the Dakota but is probably not entirely conformable; the Niobrara, however, rests upon the Benton apparently, nearly always conformable to a high degree. Indeed in many districts there is not a very marked difference between them.

In the central portion of the state the thickness of the Benton and the Niobrara reaches probably from 500 to 800 feet and the variation in thickness within considerable areas seems not to be very great. The amount and character of the material of this group indicates clearly that the deposits were made in a deep sea, and in one which for a long period of time was changing very slowly. Under no other conditions could such uniformly fine material, often mixed with a large amount of calcareous ooze, have been deposited over so great an area and with so little variation in thickness. Over most of the state the Benton is covered with Pierre and with drift, although in a few localities outcrops of this group are found. In the northern part of the state, in deep cuts along the Pembina river, the top of the Niobrara is occasionally discovered beneath the bands of Pierre shales, 350 feet or more below the general level of the land.

Along the eastern borders of the Dakota formation the Benton and the Niobrara do not appear, the Pierre seeming to over lap and rest directly upon the Dakota. In South Dakota and Nebraska are many exposures of both Benton and Niobrara, the Pierre being relatively thinner and less uniform in its extent in those states than in many places in North Dakota. From the fact that nearly all the information regarding this group in this state has been gotten from artesian well borings there has been little opportunity to study the fossil character of the deposits. From the apparent similarity of the conditions of deposition they may safely be considered about the same as those of South Dakota exposures. In this state both the Benton and Niobrara are characterized by dark blue and black shales, frequently charged with lime and often carrying iron pyrites, fragments of coal, alum and crystals of gypsum, all in very small quantities.

Pierre.—There is no formation which plays so important a part in the geology of North Dakota as the Pierre. A vast accumulation of the clays and shales of this formation is found throughout a large area in the central portion of the state, and the debris forms much of the soil and subsoil and the glacial deposits scattered over all the eastern half. The Pierre is a great deposit of clays and argillaceous shales lying immediately above the Niobrara and usually in very perfect conformity. The material is very fine and uniform, of a bluish gray color, and almost free from sand. In its lower portion it is somewhat darkened by the presence of carbonaceous matter. These shales do not carry much carbonate of lime, in which they differ markedly from the Niobrara, but they do often contain thin seams of sulphate of lime, nodules of iron pyrites and alum. A few fossils are found distributed through the deposit in various parts of the state.

Probably in no part of the state has the greatest thickness of the Pierre been penetrated. Along the deepest cuts formed by the Big Pembina river the bottom of the Pierre is reached at about 350 to 400 feet below the surrounding country, but the elevation of land increases considerably toward the northwest and in this region as in others the formation may reach a total thickness of 600 feet or more. Toward the east, however, the Pierre is known to thin out gradually until, in the Red River valley, only its debris is found.

At the international boundary the Pierre formation is seen just west of the Red River valley, where it forms nearly all the material of that conspicuous hilly escarpment known as the Pembina mountains. These hills form a very remarkable series of highlands which increase slightly in elevation toward the northwest and stretch away toward the south in a gradually descending, rolling plain. The Pembina mountains, so called, is really only the sharply eroded eastern edge of the Cretaceous formation, mostly the Pierre. This formation underlies the Turtle mountains as well as the Pembina mountains and all the intermediate country. Among the hills and along the banks of spring brooks and lakes of the Turtle mountains the Pierre is constantly appearing. From the northern highland southward through the central part of the state the Pierre is always found underlying the various deposits of drift. It is obtained from the deep well borings, is seen along many streams, and occurs as small fragments of hardened shaley blue clay on the surface of drift ridges. This fact is continually observed over the whole Devils Lake basin. To the east many of the smaller streams cut into the Pierre, and the fomation is clearly seen along the banks of the Sheyenne and James rivers.

Like the other formations of the Cretaceous, the Pierre extends over a great area beyond the limits of North Dakota. It is found chiefly in South Dakota, Nebraska, Colorado and adjoining states. The great extent of this deposit and its wonderful uniformity, especially noticeable through its whole thickness in North Dakota, clearly indicate that through a long period the area over which the Pierre is now found was a sea bottom upon which was slowly and uniformly spread a fine mud gathered from the eroded shore and carried far out to sea by currents, and that these conditions prevailed over great areas for a long time.

The Pierre is easily recognized by the color and texture of its clays and shales, but it is not entirely wanting in fossils, for several forms are found along streams in many places in the central part of the state. The more common fossils are, Baculites Ovatus, Inoceramus, Scaphites, etc. These fossils are often partly disintegrated and very commonly highly discolored by iron. Although many other forms may occasionally be found, we must still consider the Pierre in North Dakota rather barren of fossil forms. This group, with its drift debris, plays an important part over a large section of the state in the formation of soil and subsoil and in the determination of the underground water supply in the central part of the state. In

the central and eastern portion of the state it forms very generally the confining bed for the shallow wells. Water is commonly found in sand and shale debris deposited upon or inter-stratified with the Pierre.

The Fox Hills.—The Fox Hills group is not very well marked in many sections of the state. It does not appear at all in the eastern part but thin deposits are seen about Turtle mountains and south and west of Rugby Junction. Probably the formation continues still farther south along the Missouri river, and under the Laramie and later deposits in the western part of the state. The most characteristic deposits of this group are sands and sandstones, which stand out very distinctly from the Pierre, but in the Missouri district they consist largely of sandy clays and shales which grade downward into argillaceous shales of the underlying Pierre and upward into a brownish friable sandstone or a firm gray sandstone. The Fox Hills sandstone appears along the base of the Turtle Mountains and in many places doubtless separates the Laramie shales from those of the Pierre. It outcrops along the streams in several places about this district and extends to the west and southwest. Along the eastern edge it is probably very thin, but it doubtless increases somewhat in thickness toward the west. There is not sufficient data at present to determine much regarding the total area underlain by this deposit. It must be large, for the writer has found it in various places between the Turtle mountains and the Missouri and Heart rivers. Near the Turtle mountains and near Dickinson, Stark county, this sandstone develops into a good building stone, easily worked, of good color and very strong. As the demand for such material increases these deposits will undoubtedly become valuable as sources of building stone.

Laramie and Tertiary.—The Laramie and the overlying Tertiary extend over a large portion of the state west of the Missouri river. The deposit consists principally of clays and shales, some of which are excellent as fire and white-ware clays. Samples from some localities, particularly near Dickinson, Stark county, have been analyzed by the writer and show a remarkably pure material. The clay has also been burned into fire bricks of the first quality and into white earthenware of good grade. The purity and extent of these beds, taken in connection with their close proximity to inexhaustible supplies of coal and their nearness to the main line of the Northern Pacific railway, make it almost certain that they will, at no very distant period, become the source of a prosperous industry. To the same formation belong the immense beds of lignite coal which are found west of the Missouri river, extending from north of the Great Northern railway into South Dakota.

Drift.—One of the most characteristic deposits within North Dakota is the drift which is spread over a large part of the state east of the Missouri river. This deposit is made up largely of sand and clay mingled with gravel and boulders and presenting a heterogeneous mass totally unlike the sedimentary formations upon which it

lies. Any one who will thoughtfully consider the surface appearance presented over nearly all the eastern part of North Dakota will be impressed with the fact that some widely operative and powerful agency has, within a comparatively recent geologic period, been shaping surface features and accumulating, mingling and distributing over large areas the immense amount of unconsolidated foreign material which covers to a considerable thickness earlier stratified formations.

The embedding material is usually thick sheets of blue and yellow clay, sometimes alternating with beds of sand and gravel in both of which are scattered large blocks of various kinds of rocks sometimes weighing several thousands of pounds. These boulders are frequently smoothed and scored with fine parallel scratches. A knowledge of the character of these rock masses and a familarity with some of the rocks outcropping further north in Canada leads us to believe that the debris was transported from northern regions. Much of the limestone found in the drift in the northern part of the state was undoubtedly taken from the beds which outcrop about Lake Winnipeg. A study of well excavations and the channels eroded by streams shows that this drift material has covered an old land surface. In some places in the Red River valley drift and alluvial deposits reach to a depth of 300 to 350 feet. In the northern and western part of the state the thickness is commonly from 30 to 100 feet.

The agent which accomplished this gigantic work must have been a great, slowly moving ice sheet similar to that which now covers a large part of Greenland. This vast ice sheet, which in its northern portions at least must have been very deep, tore away exposed rock ledges and enveloped and bore along with it the loose material with which it came in contact. This debris was frozen into the ice and under the enormous weight above it became a mighty grinding power, and as it moved slowly but irresistibly onward from the north the enclosed rock masses were worn away to smaller fragments, pebbles, sand and clay, and all mixed with surface clays and soils. Thus was formed during the long ages of the glacial period an enormous amount of this rock refuse which, with the return of a warmer climate and the melting of the ice sheet, was intermingled and spread far and wide. This material, by reason of its variety of composition and depth of deposit is well calculated to become the foundation of the rich soil so characteristic of the eastern and central part of North Dakota.

The drift deposit is sometimes divided into till or boulder clay and stratified drift. The till is naturally the lower and consists of a heterogenous mass of clay, sand, pebbles and even large rock masses. The larger rocks are usually more angular than those in the upper stratified material and frequently show glacial marks. The till is probably derived from the material which was frozen into the lower portion of the ice sheet and was dropped as the ice melted. No doubt large floating icebergs which had stranded and melted fre-

BANKS OF MISSOURI RIVER—(UNDERLAIN BY TEN FEET OF COAL.)

quently dropped their loads of rock material over a partly stratified drift. In the central part of the state, in the Devils Lake region, the till is found commonly at a depth of from 15 to 30 feet and usually continues from 15 to 50 feet or more deep. A great number of shallow wells derive a considerable supply of water from this deposit.

The stratified drift is found immediately overlying the till. It is composed usually of fine blue and yellow clay which in many places is quite free from pebbles or boulders and shows unmistakable evidences of stratification. This material forms a thick deposit immediately under the soil in the Red River valley, along valleys of several other streams in the eastern part of the state, and over many portions of the Devils Lake drainage basin. The boulders and pebbles which are found in this upper modified drift show clearly, by their smooth and rounded surfaces, that they have been water-worn. The stratification probably took place after the retreat of the ice sheet, when the water from the melting ice had formed great lakes which filled the river valleys and lower ground and spread out over large tracts of nearly level land.

The various drift deposits which have just been mentioned indicate that a very large area in North Dakota was at a late geological period covered by a great sheet of ice which stretched far away to the north into Canada. With a change in climatic conditions the ice began to melt along its southern border and the water, being banked on the north by the great ice barrier, gradually formed a glacial lake on the southern boundary of the sheet. As the glacier continued its retreat to the north the extent and depth of the lake increased, the water spreading out over the Red River valley, and, finding no other outlet open, at last overflowed the height of land near Lake Traverse, making its way through that lake and Big Stone lake into the Minnesota river and thence into the Mississippi. Finally, however, the ice melted far enough toward the north to open a natural outlet through Lake Winnipeg and Hudson Bay, when it began forming the present valley of the Red River. The total area covered by this great lake, known as Lake Agassiz, has been estimated by Warren Upham at 110,000 square miles, over which the water often reached a depth of 500 to 700 feet. The area covered in North Dakota was about 6,000 or 7,000 square miles. After the opening of the northern outlet Lake Agassiz was rapidly drained. In the low land of the Winnipeg basin, however, a large body of water was left, a portion of which forms the present Lake Winnipeg.

The former presence of this body of water is recorded in three ways, i. e. by lacustrine sediments, by extensive alluvial and delta deposits and by corresponding extensive erosion. The fine silt and clay which is so characteristic of the Red River valley was undoubtedly deposited from the sediment of Lake Agassiz and the many glacial rivers which brought debris into this basin from the surrounding higher land. The water of the glacial Red river gradually narrowed, but being much deeper in the central portion of the

valley it remained there a longer time and thus gave opportunity for a thicker deposit of sediment than is found along the old lake margin. Mr. Warren Upham has traced a series of beaches marking clearly the extent of Lake Agassiz at its various stages. The streams which flow through the lacustrine sediments usually have narrow and shallow banks but the valley of those streams which flow into the basin of Lake Agassiz are commonly deep and wide, showing much erosion. This is particularly noticeable of the streams flowing from the Cretaceous highlands on the west, for example, the Park, Tongue, Little Pembina and Pembina rivers. Along the eastern escarpment of the Pembina mountains the erosive action of the old lake is clearly seen in the almost cliff-like ascent of the Cretaceous tablelands.

But Lake Agassiz was not the only glacial lake by which the surface of the level prairies of North Dakota was modified. In the central part of the state there were probably several lakes at various periods following the glacial epoch which were formed from the melting of arms of the ice sheet. One of the most important of these was glacial Lake Souris. Devils Lake and its immediate drainage basin is doubtless a remnant of one of these lakes. The Sheyenne and James rivers were probably started and the high bluffs along the western portion of these streams washed out during the time when districts to the north, about Devils Lake, and to the west, being flooded by the melting ice, were drained of great quantities of water by these rivers. All through the eastern and central portion of the state the ice sheet, the lakes and the river torrents formed by the melting ice, exerted a powerful influence in giving fertility to the soil and final shape to the surface of our North Dakota prairies.

CLAYS OF ECONOMIC VALUE.

The object of the following pages is to call attention, in a simple way, to some of the clays of North Dakota. Common brick is now produced in several localities in the state and at one place the manufacture of fire brick has been successfully begun. It is with the hope of making known the importance of such resources that the following outline is put in this report.

In order to get a better idea of the clays of our own state, the local descriptions will be preceded by a few general statements in regard to the source and distribution of other clays and the composition and characteristics required for various uses.

ORIGIN AND DISTRIBUTION.

The geographical distribution of clays is very extensive, yet this is true only of material adapted for the manufacture of common brick and coarse products. Deposits of clay fit for the finer uses are by no means common.

The geological horizon of clays suited to different uses varies widely from the earliest to the latest formations. Especially is this true with reference to the clays used for the manufacture of common brick and other architectural material. Coarse clays suited for these purposes are frequently found in drift-covered districts where the underlying deposits are free from sand, pebbles and excess of limestone. This is how some of the brick clay in northern Minnesota and Dakota occurs. This material is also often found as lake and river deposits which have been formed by the disintegration of surrounding or distant gneissic or feldspatic rock or from shale. It can readily be seen that clays of such origin are not likely to be of high grade on account of contamination by objectionable foreign matter.

A better grade of coarse clay is often found with the fine clays of the Cretaceous and Tertiary formations. From this some excellent brick, terra cotta, and drain pipes may be made. Some of the coarse clays of central and western North Dakota are of this kind and will doubtless prove their worth. It would naturally be inferred that material so different in its origin varies also in its composition and characteristics and so produces articles of widely different values. The essentials in every case are a sufficient proportion of true clay basis or kaolin element to produce a plastic, workable body, freedom from pebbles and from an excess of sand and fusible material. Variety in the color of brick generally results from varying proportions of iron and the intensity of the heat to

which the brick is exposed. Hard, dense, semi-vitreous brick result usually from clay with much fluxing material, such as the alkalies and iron.

Fire clay is a clay sufficiently refactory to withstand extremely high temperatures without disintegration or vitrification. Such clays are extensively used for the manufacture of linings for furnaces and fire places, in gas works and potteries, for brick and other architectural material that is liable to be subjected to great heat. For such purposes the clay must be very free from the fluxing constituents, iron and the alkalies. Good fire clay is not very common. It is found and used extensively in parts of England and in some localities on the European continent. In America it is found in New Jersey, Missouri, and some of the other states. Doubtless an excellent material exists in North Dakota, as will be seen from succeeding pages.

As to the geology, it may be said that most of the fire clays are found in the under clay of the coal measures and in the Cretaceous and Tertiary deposits. They often underlie the lignite coal beds. It is probable that the fire clays of North Dakota were part or all under the lignite, (probably in the Laramie group), although in some localities, as near Dickinson, there is no evidence of coal having been over the clay. This, however, may have been the case, the lignite having been removed from over the clay in certain spots by action of water during the great erosion to which these places have been subject.

The term potter's clay is very wide in its signification as it may mean any plastic clay from the finest porcelain and dish clay to that used for the maüfacture of coarse jugs and jars. It is evident that potter's clay fit for a good white earthenware, as well as that of lower grade for jugs, jars and the like, exists in North Dakota. We shall here consider particularly the geology of the finer clays for earthenware, etc. While clays fit for common brick and a few other purposes are quite widely distributed, fine fire clays and white earthenware and porcelain clays are rare. Clays fitted for some of the finer purposes just mentioned are found and used principally in China, in central Europe, in England and in the United States in New Jersey, Missouri and one or two other localities.

China clay, also known as Kaolin, porcelain clay, etc., is plentiful in certain localities in China. Material used for the same purpose is also found in parts of Germany and France. In England a similar clay, known as Cornish clay from Cornwall and Devon, is the basis of the great pottery and porcelain industry of Staffordshire, England.

Most of the clays used for the production of fine earthenware and the better whiteware are probably derived from the Cretaceous and Carboniferous formations, and the most extensively worked deposits of this kind in the United States are those of New Jersey. The clay from this state forms the basis of a great industry centering at

Trenton. The ware produced is of excellent quality, and the clay used is that of the Cretaceous.

While potter's clay is found to exist in several regions not particularly mentioned, and will doubtless be found in other localities, it is very certain that the finest clays, especially those fit for porcelain, will continue rare.

The clays of North Dakota, which, from this report, are shown to be suited to the production of finer grades of whiteware, are found about Dickinson, and are probably in the Laramie deposits. The best clays in this locality occur in elevations from 150 to 200 feet above the surrounding valleys. These clay knolls have escaped much of the erosion to which the surrounding country has been subject. If these deposits ever extensively covered the plain far east of Dickinson, they have probably been mostly or entirely removed by the longer action of the receding post-glacial waters as they narrowed to the present basin of the Missouri river. The ultimate source of these deposits can only be conjectured, but when we remember the ease with which fine sediment in water is transported to great distances from its original home, it does not seem impossible that the parent rock, the disintegration of which formed the basis of this clay, may have been from the feldspatic rocks occurring to the west and northwest along the flank of the Rocky mountains.

GEOLOGICAL SUMMARY OF NORTH DAKOTA CLAYS.

Post Tertiary—	Post Glacial. / Glacial	Yellow and blue brick clays of the Red River Valley; probably washed from the adjoining Cretaceous.
Tertiary—	Laramie	Plastic Clays. White earthenware and fire clays and coal of Dickinson. (Leaf prints, etc., about Dickinson, probably Laramie.) Clay and coal at Minot and at Plenty Mine, Mercer county, probably Laramie, also.
Cretaceous—		The upper non-fossiliferous shales about Park river, Langdon, are probably Cretaceous (Fort Pierre), as well as the under fossiliferous and hydraulic cement marl of the Pembina Mountain district.

The Cretaceous and Tertiary formations of North Dakota are rendered worthy of more than a passing mention by reason of their great extent and thickness, their influence upon the soil, their connection with the water supplies, and because of the large deposits of valuable clays which they contain.

The Cretaceous formation found so extensively in North Dakota is only a part of a great belt underlying deposits in a large part of the Great Western Plains. Much of it is covered by Tertiary deposits. It is made up of a series of layers placed nearly horizontally one upon the other, and usually extending over hundreds of miles in area but varying much in thickness. By subsequent pressure and chemical changes brought about through a long period, these deposits were converted in many localities into more or less

rocky material, the mud forming shale and the sand sandstone.

The formations of the Cretaceous which are well represented in the Great Plains region have been classified as follows:

Laramie, transition between Cretaceous and Tertiary. (To which probably the coal and some of the clays belong).

Cretaceous proper:
- Fox Hill
- Pierre
- Niobrara
- Benton
- Dakota

All of these subdivisions are found within the limits of North Dakota, but not all are found throughout the state, some occuring only in a few localities. In certain sections some of the groups are very thin, while in others they are very thick, ranging from a few feet to several hundred. The series is probably best developed in the central portion of the state. In the eastern part the upper group is not found while the middle and lower groups (especially the Pierre and Dakota) are not difficult to reach in well borings. In the western and northwestern parts of the state the upper groups appear commonly and are doubtless underlain by the earlier formations.

The Dakota has already been sufficiently considered as the sand and sandstone in which the artesian water usually occurs.

The Benton and Niobrara are closely associated and very similar. They are well developed in the central and northern part of the state but seldom appear along the eastern border. They are readily distinguished from the Dakota by being composed principally of blue clays and shales and are generally of very fine material. Sand is rarely present to any extent. The Niobrara and adjoining portions of the Benton are often rather strongly impregnated with carbonate of lime and often carry in small amounts iron pyrites, fragments of coal, alum and crystals of gypsum.

In the central portion of the state the Benton and Niobara together reach a thickness of from 500 to 800 feet. Over most of the states these formations are covered with Pierre and with drift. Along the deep cuts of the Pembina and Tongue rivers the top of the Niobrara is occasionally discovered beneath the Pierre shales, 350 feet or more below the general level of the land.

Pierre.—A vast accumulation of the clays and shales of this fomation is found throughout a large area in the central portion of the state and the debris forms much of the soil and subsoil and the glacial deposits scattered over all the eastern half. The Pierre is a great deposit of clays and argillaceous shales lying immediately above the Niobrara and usually in very perfect conformity. The material is very fine and uniform, of a bluish gray color and almost free from sand. In its lower portion it is somewhat darkened by the presence of carbonaceous matter.

The shales do not carry much carbonate of lime, in which they differ markedly from the Niobrara, but they do often contain thin seams of sulphate of lime. Fossils are of rare occurrence. Probably in no part of the state has the greatest thickness of the Pierre been penetrated. In the central and northwestern part of the state this formation may reach a thickness of 600 feet or more. Toward the east, however, the Pierre gradually thins out, until, in the Red River valley, only its debris is found. The Pierre supplies nearly all the material of the hilly escarpment known as the Pembina mountains as well as of the Turtle mountains and the intermediate region.

The Fox Hill group, as has already been pointed out, is not found very extensively and probably outcrops only in the western part of the state. The most characteristic deposits of this group are sands and sandstones, which stand out very distinctly from the Pierre, but in the Missouri district they consist largely of sandy clays and shales which grade downward into a brownish, friable sandstone or a firm gray sandstone. This sandstone appears along the base of the Turtle mountains and in many places doubtless separates the Laramie shales and clays from those of the Pierre. There is not sufficient data at present to determine much regarding the total area underlain by this deposit. It must be large for it occurs in severl places between the Turtle mountains and the Missouri and Heart rivers. Near the Turtle mountains and near Harvey and Dickinson this sandstone developes into a good building stone, easily worked, of good color and quite strong.

As the demand for such material increases the deposits of this stone found in some localities will doubtless become valuable for building purposes. They have already been successfully used in the construction of many buildings.

Laramie and Tertiary.—The Laramie and Tertiary extend over a large portion of the state west of the Missouri river. The deposits consist principally of clays and shales and lignite coal. Sand and sandstone is found occasionally in the upper layers. Evidently it is the lower Tertiary which is left to form the highest elevations in that portion of the state west of the Missouri and approaching the eroded region known as the Bad Lands.

The clay varies widely from a fine grained, highly aluminous blue to a coarser, silicious, nearly pure white or gray fire clay or white earthenware clay. The white clay is often mingled with red clay nodules which present a peculiar appearance. In the Bad Lands these clays have frequently been baked by the burning of the associated coal and worn by water action until the whole presents a most striking display of varied and highly colored terraces and pinnacles for which the Bad Lands are so well known.

It is certain of the white and gray clays of this formation which, about Dickinson, are, as will be seen, of unusual purity and value for fire clay products and for drain pipe, stoneware and white earthenware.

Drift.—One of the most characteristic deposits of North Dakota is the drift which is spread over a large part of the state. The material is usually thick sheets of blue and yellow clay, sometimes alternated with sand and gravel, in both of which are scattered boulders of all sizes and kinds.

In some places in the Red River valley these deposits reach a thickness of 200 to 350 feet, but in the central and western part of the state they thin down to a few feet. Above these deposits of gravel, sand and clays is the deep, rich prairie soil, formed largely from a blending of these materials with an abundant vegetable mould.

The stratified drift is composed usually of fine blue and yellow clay which in many places is quite free from sand and pebbles. It is this clay, which is found in a few localities in the eastern part of the state, that is used on such a large scale for the production of the excellent cream brick made by the various brick factories in and about Grand Forks.

CHARACTERISTICS AND COMPOSITION.

All varieties of clay originate from the disintegration of feldspatic rock. The parent rock, subject to the action of weather and water, and finally to chemical agencies, is broken, ground and separated into sand and clay. The harder pure quartz of the rock remains in coarser grains as sand and the softer feldspar, by the further wearing and chemical action, is reduced to an impalpable state and finally deposited as a bed of clay. Clays naturally partake of the character of the parent rock. For example, a rock containing much iron or alkaline matter, would be likely to form a clay containing a considerable proportion of these constituents, while a rock quite free from such ingredients, would, unless contaminated by foreign matter, produce a comparatively pure clay. Impurities are often added to clays during the time of transportation and deposition. After deposition the character of the clay is often if not always subject to a modification corresponding to the make-up of the superimposed material. Water percolating through an overlying deposition is almost sure to find some soluble constituent such as lime, iron, or alkalies, which is carried with it till it reaches the underlying clay, where, on account of the compact nature of the deposit, the water passes very slowly and so allows a portion of the elements which it holds in solution to be deposited in the clay. Thus we have another cause of the varieties of clay.

In some cases, water percolating through clay does not add impurities, but probably tends to purify it. This may be the case when coal, especially pure lignite, overlies the clay. Under such conditions the lignite probably acts much like charcoal, as an absorption filter, to remove matter in solution in the water. The water thus being left quite free from the lime, iron, alkalies, etc., instead of contaminating the under clay might, whatever works its way through, serve as a wash to carry off some of the soluble matter

of the clay. Whatever the cause, it is a fact that the purest clays very commonly underlie coal seams.

Variations in the character of the rock from which clay is derived, and variations to which the clay is subjected during and after deposition, are sure to produce clays of decidedly different character. So it is that we have clays of all grades ranging from those so impure and mixed with sand and pebbles as to be unfit for the coarsest uses, to those so pure that from them can be made the most beautiful and delicate wares.

Among the more important uses to which the coarser clays are put is the manufacture of BRICK and other ARCHITECTURAL MATERIAL. Clay fit for this purpose is quite common, especially for the inferior grades. The characteristics of clay suited to such production, are not necessarily very closely defined. In general it may be said that a good material must be free from pebbles and from too great a proportion of sand, lime and alkalies. For the common article there is not likely to be any difficulty in finding clay sufficiently free from iron or even alkalies, though a combination of these elements in too large a proportion often occurs. An excess of lime may have a tendency to give a brittle product at a low heat, or fusion at a high heat. Some clays, however, which contain a considerable amount of lime and alkalies, if properly handled, produce an excellent material where resistance and abrasive qualities are sought rather than power to withstand intense heat. As in all cases, the clay must be sufficiently plastic to work well, and must be tempered, if need be, so as to prevent too great shrinkage.

Cavities and fusion spots are often produced when the material used contains lime or pyrite nodules or fragments of organic matter. This can be largely overcome by careful grinding and mixing. The color is dependent principally upon the amount of iron present and the degree of heat to which the clay is subjected. A small proportion of iron, or, in other cases, a strong heat may produce a lighter color than would be the case with much iron or a low heat. It should be remembered that the greater portion of the produce of this class is not of the best grade. Where a superior quality can be made there is an enormous advantage to the manufacturers on account of the greater demand and higher price secured. The best grades of brick, terra cotta and drain pipes are made from inferior fire or potter's clay.

FIRE CLAY is the term given to designate those clays which possess great fire-resisting properties. The best of these clays are quite rare, though low grades are somewhat common. These clays may vary much in their original appearance from a nearly pure white to a slaty gray color. But they should bake to a white or cream color without fusion. The essential qualities of fire clays are plasticity, great freedom from lime and the fusing constituents, iron, and the alkalies, soda and potash. Iron may exist in clays in several forms; for example, as peroxide, protoxide, sulphate and sulphide. But, in whatever form, unless in small quantities, it is revealed by

the ordeal of heat in the coloration and the tendency to melt. The amount of iron which a fire clay can stand depends largely upon the lime, potash and soda it has. A clay containing only traces of these fluxing constituents may have from 3 to 5 per cent. of iron and still possess considerable fire-resisting power. If, however, a small proportion of lime and alkalies is added, the clay is useless as fire clay. The accompanying two analyses of the celebrated Stourbridge fire clay will show the variation in iron and alkalies. Analyses by Prof. F. A. Abel.*

Sample.	Silica	Alumina.	Iron Oxide	Alkali. Waste, etc.
No. 1	66.47	26.26	6.63	0.64
No. 2	63.40	31.70	3.00	1.90

Sample No. 2, containing so much less iron, is superior to No. 1, the refactory character of which may be doubted. Lime and magnesia evidently exert a considerable influence upon the fusibility of clay. It has been said that the best foreign fire clays seldom contain more than one per cent. of lime and magnesia together. Potash and soda are doubtless the most powerful fluxing constituents commonly found in clay. They unite readily with silica, forming the alkaline silicates which bring down the fusing point to a much lower temperature. There is some difference of opinion in regard to the amount of alkalies a good fire clay will stand. Snelus says that about one per cent. (of potash) is sufficient to render them unsuitable at high temperatures. Bischof found that four per cent. of potash, in a silicate of alumina without any other bases, could be fused at the melting point of wrought iron. * * * Clays containing from two to three per cent. of potash are said to stand well at high temperatures. The most carefully made analyses of the more noted and best fire clays of this country and Europe, do not generally show more than two per cent. of alkalies. From the analyses of the fire clays of New Jersey it appears that "those which are found to have one and a half to two per cent. and upwards of potash have not proved to be good fire clays."§

The amount of alkalies admissible in a fire clay depends largely upon the purity, and probably upon the physical condition of the clay. Clays having much lime and magnesia or iron, can stand but little potash and soda. In a general way it may be said that a fire clay should not contain above five per cent. of iron and alkalies together. A pure open body or coarse clay will probably stand more alkalies than it would if in other condition. What has been given may be regarded as covering the most essential characteristics of fire clays. The only way to get a safe determination of the nature and value of a given clay is to consider the clay as a whole, the resultant of the action of all its properties.

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*Wagner's Chemical Technology, p. 295

§New Jersey Geological Survey, 1878, "Clays," p. 295.

The following table of analyses will give an idea of the composition of a number of fire clays in different localities:

ANALYSES OF FIRE CLAYS FROM DIFFERENT LOCALITIES.

CONSTITUENTS.	No. 1.—New Jersey. (Used extensively.)	No. 2.—Dowlais, South Wales.	No. 3.—Newcastle-on-Tyne.	No. 4.—Newcastle-on-Tyne.	No. 5.—Stourbridge, England.	No. 6.—Frankenthal-on-Rhine, Germany.	No. 7.—Cheltenham, Missouri.	No. 8.—New Jersey, (Mid esex district.)	No. 9.—Cornwall Devonshire fire brick.
Silicon	74.30	67.12	69.25	48.55	63.40	50.00	50.80	45.60	73.50
Aluminum	18.11	21.18	17.90	30.25	31.70	31.69	31.53	38.40	22.70
Iron oxide	1.09	1.85	2.97	4.06	3.00	2.54	1.92	1.20	1.70
Calcium	0.11	0.32	--------	1.66	--------	--------	--------	0.22	
Magnesium	--------	0.84	1.30	1.91		--------	trace.	0.25	*2.10
Potassium	0.76	2.02	--------	--------	*1.90	2.22	0.40	0.59	
Sodium	0.20	--------	--------	--------		--------	--------	--------	
Water and volatile matter	5.90	7.11	7.50	10.67	--------	12.65	13.80	13.80	--------
Other matter	--------	--------	--------	--------	--------	.90	1.50	--------	--------

*Alkalies, waste, etc.

Explanation.—No. 1. New Jersey fire clay, used extensively for fire brick, retorts, etc.—N. J. Clay Report, 1878, p. 248.

No. 2. Fire clay from Dowlais, South Wales, considered the best fire clay of Dowlais.—N. J. Report from Percey's Metallurgy.

Nos. 3 and 4 are, according to Muspratt, fire clays from Newcastle-on-Tyne.

No. 5 is, apparently, the purest of several samples of Stourbridge, Eng., fire clay, analyzed by Professor Abel.—Wagner's Chem. Tech., p. 295.

No. 6, 7 and 8. Analyses from N. J. Geol. Report (clays), '78. No. 8 is considered a No. 1 fire clay, and is, perhaps, a fair sample of the New Jersey fire clays.

No. 9 is the analysis of a remarkably refactory fire brick of the Cornwall or Devonshire Kaolin.—Wagner's Chem. Tech., p. 321.

PORCELAIN AND EARTHENWARE CLAY.

Clays fit for the manufacture of a high grade porcelain or china are among the rarest clays used. For such purposes, material of the utmost purity is required. The clay should be sufficiently plastic to be readily shaped and handled; when baked it must be pure white, or nearly so, and possess reasonable strength. To give these results it must be extremely free from iron and all foreign matter that would effect color. So great freedom from alkalies is not required of porcelain and china clays as for some other purposes, since incipient fusion is necessary to produce the translucency, a characteristic of this kind of ware.

Clays of this kind are found in a few localities only and are then usually mixed with other carefully prepared ingredients. Material is extensively prepared artificially for porcelain and china. Clays of a slightly inferior grade are those used for the production of the earthenware which constitutes the most of our common white dish ware. The best earthenware clays, though not so rare as the china clays, are not very common.

It is upon this kind of clay that the great pottery industry of Staffordshire is built. Some New Jersey and other clays are now much used in making earthenware. The seat of this industry in New Jersey is at Trenton, in Ohio, at East Liverpool.

Clays for good earthenware must, besides being plastic, be as free from iron as possible, and sufficiently free from alkalies to stand high heat. They should bake white and give a strong solid body. Most of the requisites are those of a first class white, plastic fire clay. The special differences are that an earthenware clay should be freer from iron than it is necessary for a fire clay to be, and that a fire clay should be freer from alkalies than it is needful for an earthenware clay to be. For the action of the various constituents of earthenware clays refer to the discussion of fire clay characteristics.

"Clay which is pure white in color and entirely free from oxide of iron may be intimately mixed with ground feldspar or other minerals which contain potash enough to make them fusible, and the mixture still be plastic so as to be worked into forms for ware. When burned, such a composition retains its pure white color, while it undergoes fusion sufficient to make a body that will not absorb water. And its surface can be made smooth and clean by a suitable plain or ornamental glaze. Ware of this kind is porcelain or china.

"The large portion of plain white and decorated wares now sold as C. C. and white granite wares are intermediate between the old earthenware in which the body was of clay unmixed and the porcelain in which the body is of mixed earth that undergo incipient fusion when burned at a high temperature. The fine earthenwares of both kinds mentioned above are being improved in quality and appearance each year and approaching nearer in real excellence to porcelain."

Earthenware clays vary from those approaching nearly to china clay to those so impure (especially from iron) as to be unfit for white ware and called stoneware clays. "Clay containing oxide of iron in sufficient quantity to make it partially fusible in the heat required to burn it, when made into forms and burned is called stoneware clay. The heat is carried far enough to fuse the particles together, so that the ware is solid and will not allow water to soak through it; and the fusion has not been carried so far as to alter the shape of the article burned. The oxide of iron by the fusion has been combined with the clay, and instead of its characteristic red has given to the ware a bluish or grayish color. Stoneware may be glazed like earthenware, or by putting salt in the kiln when its vapor

comes in contact with the heated ware and makes with it a sufficient glaze." Clay of this kind is used largely for finer grades of jars, jugs, etc.

A considerable variety of products may be gotten by a judicious mixture of fine and inferior clays. The following table of analyses will show the composition of a number of china and earthenware clays from different localities:

CONSTITUENTS.	New Jersey ware clay.	New Jersey ware clay.	Clay used in a Trenton pottery.	China clay, Cornwall, England.	Dorsetshire clay, used in Staffordshire potteries.	Impure or unrefined Cornish-stone clay.	Porcelain Berlin.
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7.
Silicon	45.45	43.40	69.03	66.20	46.38	35.65	66.60
Aluminum	38.75	37.56	23.89	24.11	38.04	32.50	28.00
Iron	1.15	1.04	0.45	0.79	1.04	1.65	0.70
Calcium	-------	-------	0.29	-------	1.20 } trace.	trace.	0.30
Magnesium	0.11	-------	0.05	-------			0.60
Potassium	0.17	0.35	-------	0.96	} 13.44	30.05	3.40
Sodium	-------	0.37	-------	-------			
Water and volatile matter	13.05	15.40	7.46	7.20		loss 0.15	
Other matter	1.32	1.40	-------	0.20			

Nos. 1 and 2. From New Jersey Clay Report of 1878.

No. 3. From analyses made of clay from a Trenton pottery, mixed and proportioned ready for use.

No. 4. From Williams' Applied Geology.

No. 5. Muspratt gives this analyses by Mr. Higginhothan, of clay used in Staffordshire potteries.

No. 6. From Muspratt; Cornish stone clay so extensively used in fine white ware and china clay, in the impure state.

No. 7. From Muspratt, Laurent, analyst, (supposed to be from the ware, not the clay).

From what has been said it will appear that the better grades of earthenware clay are occasionally found of sufficient purity to be used in the manufacture of china, porcelain and semi-porcelain wares, while the inferior qualities run gradually into clays used for stoneware, etc. Those clays not sufficiently pure for high grade stoneware may be used in the manufacture of Rockingham and other ware. Stoneware clay may also be used for a very fine quality of drain pipe; but for much of the common drain pipe probably no better than certain high grades of brick clay is used. Earthenware clay may also be used as a fire clay in many cases and fire clays may in turn be used for earthenware. In fact the very best fire clays of

some districts are practically the same as those used for fine earthenware.

In considering the characteristics, etc., of clays, only three divisions have been made, viz: (1) Coarse clays used for bricks and terra cotta, etc.; (2) Refactory clays used for fire brick, furnace linings and various other purposes where exposure to great heat is necessary; (3) Earthenware clays used for the manufacture of white dishware.

Without going into a further study of the varieties of clays, we may take the three groups already considered as central types, to which may be referred, as modified forms, most other clays suited to uses we have not considered.

LOCAL DESCRIPTIONS.

Brick Clay.—Clays suited to the manufacture of brick are, fortunately, very widely distributed. The quality, however, varies much, and gives rise to products varying greatly in value.

North Dakota is remarkably well supplied with good brick clays. They are so well known that but little need here be said in regard to them. Fair brick clays may, I think, be found in most parts of the state. Over a considerable district in the eastern part these clays appear in two distinct beds; i. e., the upper, usually yellow clay, immediately under the soil, and the deeper blue clay. In most if not all cases in this district, brick is made from the yellow clay. Still it is quite probable that a judicious and thorough mixture of the blue and yellow clays would produce a better article.

In the north central portion of the state there are, near the surface, shale deposits of considerable thickness which would doubtless in many cases make excellent brick.

In the western portion of the state there is a variety of clays. In many localities the poorer coal clays may produce fine brick, drain and sewer pipe and terra cotta. The coal clays of medium qualities in some places will produce exceedingly fine facing brick and fancy architectural and decorative material.

It is probable that the shales about Park River, Milton, Langdon, etc., along the Great Northern railroad, and to the north along the Tongue River valley, will produce good brick, if properly utilized. They would be likely to produce a firm siliceous red brick.

Near Minot, Ward county, and Williston, on the main line of the Great Northern railroad, there are clays that will make a fine dense brick in color from light cream to red. This is not the clay used by the local yards at these places.

Near Bismarck there are two or three layers of clay fit for excellent red brick. On the bank of the Missouri river, north of the Northern Pacific railroad bridge, near Bismarck, two layers appear well suited to this use. One of these clays is a rather sandy gray clay; under this is a dark carbonaceous clay somewhat plastic and apparently adapted for making strong, dense roofing tile, brick, etc.

Some of the clays near Bismarck have been used to a large extent for brick.

About Dickinson the great variety of fine clays afford abundant material for the finest kind of brick, terra cotta, pipe material of different kinds, etc. The best of these clays run into fine fire clay and earthenware clay, and seem too valuable to be used for common brick. They will be further considered under the head of fire and earthenware clay.

The Mouse River Lignite Coal Company, at Burlington, Ward county, on the "Soo" railway, has recently established a plant for making common brick. Two or three kilns were burned late during the past season. With careful development it is evident that an excellent common brick for local use can be produced. The clay used is taken from the hill above the entrance to the coal mine. It is mostly yellow drift clay. Other clay may be utilized.

In the Red River valley the yellow clay immediately under the soil affords material for a first class cream brick. It is the clay used extensively at Grand Forks. The Red River Valley Brick Company is an association of brick manufacturers of Grand Forks, North Dakota, and East Grand Forks, Minnesota. There is one factory on the Minnesota side and three in Grand Forks on the North Dakota side. The annual product of these three yards is about 9,000,000, with a value of about $59,000. Seventy-five men are employed by these three factories and from 4,000 to 5,000 cords of wood are consumed in the manufacturing process.

The yellow clay of the glacial drift is used. The brick is of a cream color and is hard and strong. Its excellent quality is generally recognized and the sales extend quite widely over the northwest. Shipments are made as far east as the lakes and to the west far into Montana; to the north into Canada, and to the south into the central part of South Dakota.

At Fargo brick is made from clay similar to that used in the factories in Grand Forks. The industry has not been carried on so far at this place, however. The annual production is about 1,500,000.

At Drayton, Walhalla and several other points the manufacture of brick is carried on in a limited way to supply local consumption.

The following are analyses of several North Dakota clays which may be used for brick, etc.

CONSTITUENTS.	Grand Forks.	Bismarck.	Williston.
Silicon ($Si O_2$)	51.27	58.73	57.80
Aluminum ($Al_2 O_3$)	9.33	14.98	9.47
Iron oxide $Fe_2 O_3$	3.52	5.63	3.16
Calcium ($Ca O$)	11.15	2.10	7.91
Magnesium ($Mg O$)	2.31	0.74	2.84
Sodium ($Na_2 O$)	2.08?	0.988	?
Potassium $K_2 O$	0.50 ?	0.16	
Water and volatile matter*		16.672	
Other matter			

*By subtraction. All very moist.

Remarks—No. 1, clay used at Alsip's brick works. No. 2, not used; found on bank of Missouri river near Bismarck. No. 3, not used; associated with coal near Williston. In the laboratory furnace, No. 1 baked cream; No. 2, red, very firm; No. 3, cream.

Most of the coarser grade of title, drain and sewer pipe may be made from extra fine brick clay, but the best of such material is a little more exacting in its clay used, although it is very often classed with brick clay. Under brick clay, some places were mentioned where doubtless fair tiling and pipe clay may be found.

Clays fit for high grade articles of this kind should possess sufficient plasticity and tenacity to be readily moulded into varied shapes, and strength to resist too easy crushing. They must have enough quartz material to prevent cracking and shrinking, and for many purposes should be quite refractory, since they are baked at strong heat and may in after use be exposed to high temperatures.

A considerable difference in the product may be made by the use of a good plastic clay and varying proportions of sand.

Near Minot, on the main line of the Great Northern railway, and near Burlington, Ward county, on the "Soo" railway, one or two very good clays are found associated with the coal of that locality. A few miles northwest of Minot coal is mined from the bluffs that rise from the old valley of the Souris river. At the old Colton mine the coal is found in a nearly horizontal layer, probably 8 to 12 feet thick and about 12 feet below the top of the bluff. Most of the covering material above the coal appears to be clay and sand. Just above the coal there is a layer of fine clay of a slaty gray color and a smooth, greasy feel. The layer appears to be several feet thick. This clay would probably make an excellent architectural material for the finer ornamental purposes. Its compostion is shown by the following analysis:

Silicon ($Si O_2$)	56.86
Aluminum ($Al_2 O_3$)	25.03
Iron oxide ($Fe_2 O_3$)	6.11
Calcium ($Ca O$)	0.71
Magnesium ($Mg O$)	0.76
Potassium ($K_2 O$)	0.50
Sodium ($Na_2 O$)	0.016
Water and volatile matter / Other matter } By subtraction	10.014

In Mercer county on the Missouri river, a clay is found associated with the coal which is very similar to the Minot clay just described. It has about the same texture, color and feel, and after being baked looks much the same. It could therefore be used for the same purposes as the Minot clay. The analysis of this clay is as follows:

Silicon ($Si\ O_2$)	60.79
Albminum ($Al_2\ O_3$)	16.23
Iron oxide ($Fe_2\ O_3$)	4.49
Calcium oxide ($Ca\ O$)	0.65
Magnesium oxide ($Mg\ O$)	1.02
Potassium oxide ($K_2\ O$)	0.19
Sodium oxide ($Na_2\ O$)	0.28
Water and volatile matter / Other matter } By subtraction	16.35

At Bismarck, along the bank of the river near the Northern Pacific railroad bridge, there are two layers of clay, both of which may be used for the purposes described in this section. These two clays occur about 50 feet above the river. The upper layer is several feet thick, is of a dark grayish color and mixed with a little finely pulverized sand. Just under this is a finer, more plastic, chocolate-colored clay of uniform texture. The color is due in part to the presence of carbonaceous matter. On burning, it becomes a light red. When baked, it posses a hard, compact, ringing body. The thickness of the layer is not known, but of the two layers there is probably a deposit of not less than six or eight feet. There is but little doubt that this clay would be valuable for several uses. It could be mixed with the clay above which is much like it and would then make an excellent drain and sewer pipe and a good ornamental building material. An analysis of this clay shows:

Silicon ($Si\ O_2$)	58.73
Aluminum ($Al_2\ O_3$)	14.98
Iron oxide ($Fe_2\ O_3$)	5.63
Calcium oxide ($Ca\ O$)	2.10
Magnesium oxide ($Mg\ O$)	0.74
Potassium oxide ($K_2\ O$)	0.16
Sodium oxide ($Na_2\ O$)	0.988
Water and volatile matter / Other matter } By subtraction	16.672

About Dickinson there is a great variety of clays, some of which, being too poor for earthenware and fine refractory material, will make good semi-fire-brick and other inferior refractory articles, besides tiles, pipes, and the finest ornamental building material. By mixing the clays found in this vicinity, material can be had for a large number of uses. A mottled clay, said to occur in large quantities, seems remarkably well suited to the manufacture of terra cotta and ornamental material. This clay appears very much like some of the mottled clay from Martha's Vineyard. It has a fine white body dotted with patches of red. It is all very free from grit and when ground makes a uniform body of a light red color.

It is very plastic, but stands heat well without cracking or warping. The following is an analysis of this clay:

Silicon ($Si\ O_2$)	56.03
Aluminum ($Al_2\ O_3$)	24.23
Iron oxide ($Fe_2\ O_3$)	9.46
Calcium oxide ($Ca\ O$)	----
Magnesium oxide ($Mg\ O$)	0.31
Potassium oxide ($K_2\ O$)	0.088
Sodium oxide ($Na_2\ O$)	0.72
Water and volatile matter	9.39

This clay will be seen to be remarkably free from all fusing constituents excepting iron. By properly mixing the fine white clay found in the same locality (described under fire and earthenware clay) a fairly refractory material would be gotten, fit for some grades of fire brick, saggars and many other purposes.

A few miles east of Dickinson, at the Lehigh mine on the Northern Pacific railway, the clay which underlies the coal may, without doubt, be used for some of the purposes mentioned in this section. At this place lignite coal is quite extensively mined. The nearly horizontal layer of coal outcrops from the side of a bluff, about 100 feet or 250 feet below the top, and is from 8 to 15 feet or more in thickness. It is mined by a tunnel from the side. The coal is capped by a layer of pure gray clay 5 to 10 feet thick, which may be used for common brick, if properly mixed with other clays and not subjected to too severe heat. The analysis of this clay gives:

Silicon ($Si\ O_2$)	55.77
Aluminum ($Al_2\ O_3$)	12.15
Iron oxide ($Fe_2\ O_3$)	4.27
Calcium oxide ($Ca\ O$)	5.92
Magnesium oxide ($Mg\ O$)	1.90
Potassium oxide ($K_2\ O$)	0.256
Sodium oxide ($Na_2\ O$)	0.992
Water and volatile matter, etc., by subtraction	18.742

This clay bakes to a buff color, stands low heat well, but shows a tendency to fuse at high temperature.

The clay under the coal is of better quality than that above. It is dark colored and of a soapy feel. The dark color appears to be due to the large amount of carbonaceous matter. When baked it takes on a light gray color. A proper admixture of these clays with a rather sandy clay would, if properly manufactured and burned, probably make a very good quality of paving blocks.

The following illustration will give an idea of the formation. The outcrop which appears in this cut is some distance from the mine. It shows only a small portion of the layer of coal and none of the under clay.

Soil, Sand, and Clay

Clay (upper)
Thickness, 12 to 16 feet.

Coal (lignite)
Showing a portion of the layer

NEAR THE LEHIGH COAL MINE

The following is an analysis of the under clay after burning to remove carbon:

Silicon ($Si O_2$)	71.25
Aluminum ($Al_2 O_3$)	21.94
Iron oxide ($Fe_2 O_3$)	3.67
Calcium oxide ($Ca O$)	0.74
Magnesium oxide ($Mg O$)	0.83
Potassium oxide ($K_2 O$)	----
Sodium oxide ($Na_2 O$)	----
Water and volatile matter, by subtraction	----

About Dickinson, higher grade clays abound which are too valuable to be used for the purposes named in this division. These will be considered under fire and earthenware clays.

For comparison, we insert the following analyses of clays of this character found in other localities, and used for the purposes we have just considered:

CONSTITUENTS.	No. 1.—Wakerly Buff clay.	No. 2.—Watcombe Red clay.	No. 3.—Brosley Red Clay.	No. 4.—Dunfermline Red clay.	No. 5.—Saggar Clay Staffordshire Potteries.	No 6.—Rockingham and Brick clay.
Silicon	69.59	57.83	64.06	64.14	54.38	58.07
Aluminum	20.04	20.55	20 60	13.34	26.55	27.38
Iron	3.37	7.75	7.16	7.57	8.38	3.30
Calcium	3.16	1.68	0.12	1.90	......	0.50
Magnesium	3.18	0.97	0.04	......	......	......
Potassium	......	3.87	0.91	1.54	......	
Sodium	......	.56	0.44	......	......	10.30
Water, organic matter and loss	......	6.52	5.85	......	7.28	
Other constituents	......	0.90	0.71	......	3.14	......

Nos. 1, 2, 3 and 4 are terra cotta and tile clay analyses taken from Spon's Encyclopedia of Industrial Arts, and are said to stand fire well and to be much used.

No. 5. Staffordshire saggar clay, "Burns light buff, a fire brick," from Dobson's Brick and Tile, p. 115.

No. 6. "A yellow midland counties clay, used for brick and Rockingham pottery," Dobson's Brick and Tile, p. 264.

The following are analyses of North Dakota clays:

CONSTITUENTS.	No. 1.—Minot, above coal.	No. 2.—Mercer County.	No. 3.—Near Bismarck, on bank of Missouri river.	No. 4.—Dickinson Buff clay.	No. 5.—Upper White clay, Lehigh Coal Mine.	No. 6.—Under clay at Lehigh Coal Mine.
Silicon ($Si\ O_2$)	56.86	60.79	58.73	56.03	55.77	71.25
Aluminum ($Al_2\ O_3$)	25.03	16.23	14.98	24.23	12.15	21.94
Iron ($Fe_2\ O_3$)	6.11	4.49	5.63	9.46	4.27	3.67
Calcium ($Ca\ O$)	0.71	0.65	2.10	------	5.92	0.74
Magnesium ($Mg\ O$)	0.76	1.02	0.74	0.31	1.90	0.83
Potassium ($K_2\ O$)	0.50	0.19	16.672	0.088	0.256	?
Sodium ($Na_2\ O$)	0.016	0.28	0.988	0.72	0.992	
Water and volatile matter, etc.	10.014	16.35	0.16	9.39	18.742	
Other matter and errata	------	------	------	------	------	

By a comparison of an analysis of these clays with the preceding analyses given of clays from England and other localities, used for the purposes under consideration, it will be seen that with one or two exceptions the North Dakota clays are of considerably better quality. In nearly, if not all cases, the clays are easily mined. In most cases they are found immediately associated with coal or where it can be had at small cost. This is a great advantage to North Dakota clays. The fuel question is one of paramount importance, since it is one of the largest sources of expense in the manufacture of clay products. The abundance of fuel, which can be gotten for a mere trifle where most of those clays are found in connection with lignite coal, will aid wonderfully in making the manufacture of clay articles an extensive and profitable industry.

Fire Clay, Etc.—We now come to the consideration of one of the rarest and most valuable of clays. Fire clay is sought for a number of important uses for which ordinary clay is far too poor and for which no other kind can be satisfactorily used. The following are some uses to which a good fire clay is put, viz: for fire brick, retorts for gas works, glass works and metal works, for crucibles, for special use in fire proof buildings, and in furnaces, ovens, flues, fire proof safes, etc., etc.

The essential characteristics of fire clay have already been considered. The finer fire clays are not essentially different from fine earthenware clays and are often extensively used for pottery. There is only one locality in North Dakota known to the writer where the finest grade of fire clay is found.

About Dickinson, Stark county, there are several clays which may be considered first quality fire clays. The origin of these clays

can only be guessed. It has already been stated that they are found in the Laramie formation. The finest clays in this locality occur in elevations 100 feet or more above the surrounding valley. These clay knolls have escaped much of the erosion to which the surrounding country has been subjected. If these deposits ever extensively covered the plain far east of Dickinson, they have probably been mostly or entirely removed by the longer action of the receding water, glacial or post-glacial, as it narrowed to the present basin of the Missouri river. The ultimate source of these deposits is a matter for conjecture. It is not impossible that they were once feldspatic rocks occurring to the west and northwest along the flank of the Rocky mountains.

The clays of this character which the writer has examined, about Dickinson, outcrop from near the top of high bluffs. In some cases the surface soil and clay seems to have been entirely washed away and the white fire and earthenware clay is left capping the bluff. This is the case with a deposit of very fine clay which occurs about one mile south of Dickinson. At this point the bluff is about 100 feet high. The base appears to be principally of sand and clay. Above this is a very thick layer, probably from 10 to 15 feet of fine white fire clay; above this is a layer, perhaps four feet thick, of still purer white clay, which caps the hill where not washed away. This upper clay is intimately mixed with a small amount of sand, which gives it a rough feel. As taken from the layer, the lumps are soft enough to be crushed in the hand. When baked it produces a hard body which shows little tendency to fuse. The color becomes a pure white, purer than before baking, which indicates that a small amount of carbonaceous matter was present in the unbaked material. An analysis of this clay shows the following:

Silicon ($Si\ O_2$)	72.66
Aluminum ($Al_2\ O_3$)	17.33
Iron ($Fe_2\ O_3$)	1.05
Calcium ($Ca\ O$)	0.13
Magnesium ($Mg\ O$)	----
Potassium ($K_2\ O$)	0.36
Sodium ($Na_2\ O$)	0.38
Water and volatile matter Other matter	9.35

From the analysis it will be seen that this is a very pure clay. The silicon appears rather high in proportion to the aluminum, but this is due to the presence of a small amount of sand. For most purposes the silicon does not appear too high. The iron, it will be noticed, is very low, while there is scarcely more than a trace of calcium, and the alkalies are also low. In all respects this clay seems to be an exceedingly fine fire clay.

The clay, as has been stated, found immediately under this, is a layer about 10 feet thick. It is very fine and free from grit, and can be dug with a spade and pulverized in the hand. Its color when dug is grayish white, probably due to a slight amount of carbonaceous matter, but after baking it becomes a pure white.

It has a very firm homogeneous body, and when baked becomes very hard with a clear, sharp ring. This clay has been subjected to intense heat in the laboratory furnace and stands perfectly without cracking or warping. The analysis of a sample taken from a surface exposure gives:

Silicon ($Si O_2$)	64.84
Aluminum ($Al_2 O_3$)	24.31
Iron ($Fe_2 O_3$)	1.60
Calcium ($Ca O$)	0.11
Magnesium ($Mg O$)	0.24
Potassium ($K_2 O$)	trace
Sodium ($Na_2 O$)	0.32
Water and volatile matter / Other matter	8.58

This analysis shows a very pure clay and one well proportioned for immediate use. The fluxing constituents are so small in amount as hardly to need notice. The iron is also small for an unwashed, surface specimen. A large number of samples of this clay have been tested at the laboratory of the University and have shown exceedingly high fire resisting qualities. Samples of these clays have also been sent by the writer to one of the best fire brick experts in a well known eastern fire brick factory. The results were perfectly satisfactory and the clay, after being worked in a practical way, was pronounced a first class fire clay.

The surroundings are all that could be desired. At the foot of the bluff where the clay is found there is a small stream which furnishes water to a factory owned by the Dickinson Fire Brick Company. The deposit is probably not more than one mile from the main line of the Northern Pacific railway. Coal is mined on the company's land. There is no doubt but what this clay, as well as the one mentioned before it, is unusually well suited for the highest grade of fire material, and there seems to be an abundance of it.

The Dickinson Fire & Pressed Brick Company have successfully started the development of the fire clay and other brick clays at Dickinson. This company has about completed a large plant capable of producing fine pressed brick of various grades and colors from a white to a red, or the great variety of fire brick products. The plant is a thoroughly modern one. The machinery is of the best make. The brick machine gives a maximum pressure at each stroke of 200,000 pounds, or 40,000 pounds for each brick. The kilns are large, permanent ones of most modern design and so constructed as to admit of intense and uniform burning. The whole plant has recently been provided with a continuous hot air fan system for the purpose of utilizing as fully as possible all the heat ordinarily lost from brick kilns. The fuel used is lignite coal which is mined from the company's land near the plant. Under the blast system employed it gives the most satisfactory results for both steam and kiln heat.

The quality of the brick produced at this plant is excellent. The fire brick is worthy of special notice. A great variety of grades

DICKINSON FIRE BRICK CO.'S PLANT.

have been produced suited to the widely different uses to which fire brick is put. The fire resisting qualities of this brick are beyond question. The bricks have been tested side by side with the best and most popular fire bricks of this country, and in several instances they have withstood a higher temperature than other standard brands. They have stood well under the severe tests in which the pyrometer indicated 3,500 degrees and upwards. They have been put to the trial successfully in forges, iron furnaces, boiler settings, blast furnaces, coke ovens and in several other places.

This is certainly a high grade fire material, and as soon as time enough has elapsed to remove the prejudice which a new article always has to contend with, it is safe to predict that the value of this product will be recognized and its use widely extended in the northwest. The present capacity of the plant is 40,000 per day. There are from 20 to 30 men employed. The accompanying cut shows a portion of the plant.

For the purpose of comparison, analyses are given of a number of fire clays found in different parts of the world, and extensively used for various refractory purposes.

TABLE "A."

Analyses of Fire Clays from various localities.	No. 1.—New Jersey. (Used extensively.)	No. 2.—Dowlais, South Wales.	No. 3.—Newcastlt-on-Tyne.	No. 4.—Newcastle-on-Tyne.	No. 5.—Stourbridge, England.	No. 6.—Frankelthal-on-Rhine, Germany.	No. 7.—Cheltenham, Missouri.	No. 8.—New Jersey. (Middlesex district.)	No. 9.—Cornwall or Devonshire Fire Brick.
Silicon	74.30	67.12	69.25	48.55	63.40	50.00	50.80	45.60	73.50
Aluminum	18.11	21.18	17.90	30.25	31.70	31.69	31.53	38.40	22.70
Iron	1.09	1.85	2.97	4.06	3.00	2.54	1.92	1.20	1.70
Calcium	0.11	0.32	-------	1.66	-------	-------	-------	0.22	
Magnesium	-------	0.84	1.30	1.91		-------	trace.	0.25	
Potassium	0.76	2.02	-------	-------	*1.90	2.22	0.40	0.59	†2.10
Sodium	0.20	-------	-------	-------		-------	-------	-------	
Water and volatile matter	5.90	7.11	7.50	10.67	-------	12.65	13.80	13.80	-------
Other matter	-------	-------	-------	-------	-------	0.90	1.50	-------	-------

*Alkalies, waste, etc.
†Alkalies and waste.

No. 1. New Jersey fire clay, used extensively for fire brick, retorts, etc. N. J. Clay Report, p. 248.

No. 2. Fire clay from Dowlais, South Wales, considered the best fire clay in Dowlais. N. J. Report from Percy's Metallurgy.

Nos. 3 and 4 are, according to Muspratt, fire clays from Newcastle-on-Tyne.

No. 5 is, apparently, the purest of nine samples of Stourbridge, Eng., fire clay, analyzed by Professor Abel. Wagner's Chem. Tech., p. 295...

Nos. 6, 7 and 8. Analysis from N. J. Geol. Report (Clays) '78. No. 8 is considered a number one fire clay and is, perhaps, a fair sample of the higher grade fire clays of New Jersey.

No. 9 is an analysis of a remarkably refractory fire brick of the Cornwall or Devonshire Kaolin. Wagner's Chem. Tech., p. 321.

TABLE "B."

CONSTITUENTS.	No. 1.—Dickinson, (upper.)	No. 2.—Dickinson, (under No. 1.)	No. 3.—Dickinson.
Silicon ($Si\ O_2$)	72.66	64.84	64.22
Aluminum ($Al_2\ O_3$)	17.33	24.31	17.22?
Iron ($Fe_2\ O_3$)	1.05	1.60	2.09
Calcium ($Ca\ O$)	0.13	0.11	trace
Magnesium ($Mg\ O$)	....	0.24	0.37
Potassium ($K_2\ O$)	0.36	trace	0.21
Sodium ($Na_2\ O$)	0.38	0.32	0.34
Water and volatile matter	9.35	8.58	10.29
Other matter and errata	....	....	....

In making comparisons of the analyses of the clays it must be remembered that in all cases the North Dakota clays were unwashed, and in most cases as dug from surface exposures. By reference to the tables of analyses it will be seen that No. 1 of North Dakota clay corresponds quite nearly to No. 1 of the other list, which is a New Jersey clay, extensively used for fine fire clay. The advantage, however, appears in favor of the North Dakota clay, since it contains less iron and alkalies. It also seems superior to any of the other foreign clays of list "A," with the possible exception of No. 8. North Dakota sample No. 2 corresponds most nearly to No. 2, and No. 9 of table "A," clays from Dowlais, South Wales, and from Devonshire and Cornwall, England. The North Dakota sample again appears superior on account of its great freedom from iron and alkalies.

Sample No. 3 of North Dakota clays, though probably not quite so good as Nos. 1 and 2, is, however, of fine quality and doubtless superior to the most of the clays in table "A."

When we consider the quality of the clays, the ease with which they can be mined, the abundance of the clay and the almost inexhaustible supply of cheap coal near the most of it, the surrounding markets and the means of transportation at hand in most cases,

there seems to be no reason why these clays should not become the basis of an extensive and profitable industry.

Potter's Clay.—The term potter's clay is very loosely used to designate a great variety of plastic clays. For convenience, we shall in this article make but two divisions of potter's clay, viz: stoneware and earthenware clays. These two clays are those used most extensively for common dishware; the stoneware being the poorer quality and the earthenware, the finer white dishware, largely used for tableware.

Stoneware Clays.—The essential requisites of this class of clays are: Plasticity, fineness, freedom from an excess of impurities, such as iron and alkalies, ability to stand heat well and to produce a strong, impervious body. There is a wide variation in stoneware clays. The poorer grades are but a little better than a good brick clay, while the finest approach very close to earthenware clays. The typical stoneware clays bake to a strong, sonorous and sometimes semi-vitrified body. They are usually not so fine nor so homogeneous as the earthenware clays. The ware, after baking, is opaque and commonly of a gray or yellow color, due largely to the presence of a considerable quantity of iron. The coarser stoneware is usually salt-glazed, but the finer quality may be decorated and glazed similar to earthenware. Stoneware may be used for common yellow and gray ware, for jugs, jars, plumber's ware, a cheap quality of dishware and for many other purposes.

In North Dakota there is one locality where stoneware clay is found. The material is from fair to fine in quality. About Dickinson there are several clays which will make excellent stoneware. But the best of these are too good to be used for anything but the highest grade white stoneware, which is the next thing to earthenware. Some of the better of these clays will be described under earthenware clays. An analysis of a sample furnished by Mr. E. F. Messersmith gave the following results:

Silicon ($Si O_2$)	64.22
Aluminum ($Al_2 O_3$)	17.22?
Iron ($Fe_2 O_3$)	2.09
Calcium ($Ca O$)	trace
Magnesinm ($Mg O$)	0.37
Potassium ($K_2 O$)	0.21
Sodium ($Na_2 O$)	0.34
Water and volatile matter	10.29

For the purpose of comparison, the following analyses are given of clays used for stoneware in various localities in other parts of the world.

1. Unglazed stoneware, Baltimore, very fine white body.*

*From Muspratt.

Silicon	67.40
Aluminum	29.00
Iron	2.00
Calcium	0.60
Magnesium	----
Potassium / Sodium	0.60

2. According to Salvetat,§ fine yellow wedgewood ware consists of:

Silicon	66.49
Aluminum	26.00
Iron oxide	6.12
Calcium	1.04
Magnesium	0.15
Alkalies	0.20

3. From analyses of stoneware by the same as No. 2, the following results are secured.

Silicon	from 62	to 75	per cent.
Aluminum	from 19	to 29	per cent.
Iron oxide	from 1	to 8.5	per cent.
Calcium	from 0.25	to 1	per cent.
Magnesium	from 0	to 0.9	per cent.
Alkalies	from 0.50	to 1.5	per cent.

Most of the stoneware clays of New Jersey seem to be of superior purity, especially with reference to iron. By comparing the analyses of stoneware clays from various localities with those of the same class in North Dakota it will be seen that, as far as chemical analyses show, the clays mentioned from this state are apparently of very fair quality.

There can scarcely be any doubt but what these clays will produce an article fully equal to the average of this class of ware.

Earthenware Clays.—The purest, finest stoneware clays grade insensibly into earthenware clays.

Earthenware clay possesses the general characteristics of fine stoneware clay. A good earthenware clay must be highly plastic, very free from iron and excess of alkalies, and must bake to a strong, compact white body.|| Such clay is the material used for most of the white tableware. The comparative rarity of this clay and the large number of uses to which it can be put, on account of its purity, add much to its value.

As has already been said, clay of this kind is found in England and extensively used in the great pottery industry of that country. In the United States, the fine clays of this quality form the basis of the great pottery industry of New Jersey.

In North Dakota there is at least one district where there are large deposits of clay apparently well suited to the manufacture of

§Beckwith's "Pottery" pamphlet, p. 24.

||See the general remarks under Characteristics.

White Fire and Earthenware Clay. Probably 3 to 5 feet.

Fine White Earthenware and Fire Clay. Probably 10 to 15 feet thick.

Sand and Clay

Soft Sandstone

Sand and Clay

Probably 100 feet or more in height

NEAR DICKINSON (ABOUT ONE OR TWO MILES SOUTH.)

earthenware. These clays are found in the southwestern part of the state, in the vicinity of Dickinson, Stark county.

These deposits have already been mentioned in connection with the fire clays. The description of some of these will be repeated in this section. The clays of this class (white earthenware clays) found about Dickinson, outcrop near the top of high bluffs. In some cases the surface soil and clay seem to have been entirely washed away and the white clay is left capping the bluff. This is the case with a deposit of very fine white clay about a mile south of Dickinson. At this point the bluff is probably 100 feet or more high. The base of the bluff appears to be chiefly of sand and clay. Above this is a very deep layer, probably from 10 to 15 feet thick, of fine, white earthenware clay. This seems to be covered by a layer, perhaps four feet thick, of very pure but slightly sandy clay. A cut of this deposit is given on the opposite page.

This upper clay as found is of a very light color, but bakes still whiter. It produces a hard body showing little tendency to fuse. An analysis of this clay, as dug, is as follows:

Silicon ($Si\ O_2$)	72.66
Aluminum ($Al_2\ O_3$)	17.33
Iron ($Fe_2\ O_3$)	1.05
Calcium ($Ca\ O$)	0.13
Magnesium ($Mg\ O$)	----
Potassium ($K_2\ O$)	0.36
Sodium ($Na_2\ O$)	0.38
Water and volatile matter	9.35

It will be seen from the analysis that this is a very pure clay. The silicon appears rather large in proportion to the aluminum, but this is due to the presence of a small amount of sand which, if necessary, could be removed probably with very little trouble. The iron, it will be noticed, is very low for a surface specimen unwashed. The amount of alkalies is small. Withal this clay would probably, with proper treatment, make excellent earthenware material suited for common white tableware, etc. The clay, which it has been said, is found immediately under this, is a layer perhaps from 10 to 15 feet thick. This clay is very fine and free from grit. It can be dug with a spade and the lumps can be powdered in the hand. The color of the clay as dug is a grayish white, probably due to a slight amount of carbonaceous matter. After baking, it is pure white. It has a very fine homogeneous body. When baked it becomes very hard and has a clear sharp ring. It stands heat well without warping or cracking. An analysis of a sample taken from a surface exposure, and as dug, gives:

Silicon ($Si\ O_2$)	64.84
Aluminum ($Al_2\ O_3$)	24.31
Iron ($Fe_2\ O_3$)	1.60
Calcium ($Ca\ O$)	0.11
Magnesium ($Mg\ O$)	0.24
Potassium $K_2\ O$)	trace
Sodium ($Na_2\ O$)	0.32
Water and volatile matter, etc., by subtraction	8.58

This analysis shows a very pure clay and one which, when washed and purified, seems well proportioned for the potter's use. The fluxing constituents and the iron are not high for an unwashed surface specimen..

A large number of small dishes were made from these clays and baked in the furnace of the laborataory at the University. The bisque came out a very fine, white, compact body. It had a good ring and showed no tendency to crackle or warp. After these tests were made large lots of the clay were shipped to many of the leading potteries of this country and there the clay was made into a variety of dishes, such as cups, saucers, plaques, pitchers, etc., and then baked and glazed. In nearly all cases the results were satisfactory and the clays were pronounced by the potteries to be of a high grade and of great value. These made-up dishes may be seen at the State University museum.

A sample of clay which had been cleaned and mixed and tempered ready to be formed, just as used, was taken from one of the large Trenton potteries and analyzed with the following results:

Silicon ($Si\ O_2$)	69.03
Aluminum ($Al_2\ O_3$)	23.89
Iron oxide ($Fe_2\ O_3$)	0.45
Calcium oxide ($Ca\ O$)	0.29
Magnesium oxide ($Mg\ O$)	0.05
Water and volatile matter	7.46
Potassium ($K_2\ O$) } ?	----
Sodium ($Na_2\ O$) }	

By comparing this analysis with the last mentioned from North Dakota, it will be seen that there is, in some respects, a considerable similarity in composition. The North Dakota clay is a little higher in iron, but it must be remembered that the sample from the Trenton pottery had been washed and thoroughly prepared for ware, while the sample from North Dakota was just as dug. There is but little doubt that this clay is well suited for white tableware and the like uses. The supply of the clay is evidently abundant. The surroundings are all that could be asked. At the foot of the bluff where the clay is found, there is a small stream which would furnish water for the factory. The deposit is probably not more than a mile and a half from the main line of the Northern Pacific railway. So a spur track could be easily run to the deposit. Coal is found in great abundance and is mined within a few miles and can be gotten at a very low price. There is plenty of material for saggars in which to bake the ware.

There are doubtless other good earthenware clays in this vicinity, although the writer has not visited any such deposits. However, samples of one or two other fair clays have been received and analyzed. The analysis of a sample from about Dickinson, furnished by Mr. E. F. Messersmith gave the following results:

Silicon (SiO_2)	64.22
Aluminum (Al_2O_3)	17.22?
Iron (Fe_2O_3)	2.09
Calcium (CaO)	trace
Magnesium (MgO)	0.37
Potassium (K_2O)	0.21
Sodium (Na_2O)	0.34
Water and volatile matter	10.29

Good earthenware clays may be discovered in other parts of the state, but no such deposits are known to the writer. For the purpose of comparison, analyses are given of a number of earthenware clays found in different parts of the world, and extensively used for the manufacture of whiteware, etc.:

CONSTITUENTS.	No. 1.—New Jersey ware clay.	No. 2.—New Jersey ware clay.	No. 3.—Clay used in a Trenton pottery.	No. 4.—China clay, Cornwall, England.	No. 5.—Dorsetshire clay, used in Staffordshire potteries.	No. 6.—Impure or unrefined Cornish stone clay.	No. 7.—Porcelain, Berlin.
Silicon	45.45	43.40	69.03	66.20	46.38	35.65	66.60
Aluminum	38.75	37.56	23.89	24.11	38.04	32.50	28.00
Iron	1.15	1.04	0.45	0.79	1.04	1.65	0.70
Calcium	....	....	0.29	....	1.20	trace.	0.30
Magnesium	0.11	....	0.05	....	trace.		0.60
Potassium	0.17	0.35	....	0.96	....		3.40
Sodium	....	0.37	....	....	....	30.05	....
Water and volatile matter	13.05	15.40	7.46	7.20	13.44		....
Other matter	1.32	1.40	....	0.20	....	loss 0.15	....

Nos. 1 and 2. From New Jersey Clay Report of 1878.

No. 3. From analysis made of clay from a Trenton pottery, mixed and proportioned ready for use.

No. 4. From Williams' Applied Geology.

No. 5. Muspratt gives this analysis, by Mr. Higginbotham, of clay used in Staffordshire potteries.

No. 6. From Muspratt, Cornish-stone clay, so extensively used in fine white ware, and China clay, in the impure state.

No. 7. From Muspratt; Laurent, analyst. (Supposed to be from the ware, not the clay.)

Conclusion.—From what has been said it may justly be concluded that North Dakota is richly supplied with a variety of valuable clays. The excellent brick clays which are so widely distributed throughout the state are sure, as the country develops and the cities and towns increase in size and number, to become very important factors in growth, in substantiality and in beauty.

Sooner or later the superior brick clays of several localities are likely to become known and appreciated and their products sought by cities of neighboring states. Growth and improvement in the cities will also tend toward developing the clays fitted for sewer and drain pipes, for various sanitary and other purposes.

There seems no reason why those districts supplied with good fire clay may not soon become centers of a lively industry in manufacturing fire brick and other refractory material. A very promising industry has already been started in this line at Dickinson.

There are some excellent stoneware and probably good white earthenware clays. The constant demand for articles of these wares may be expected to result in establishing factories for their production.

There is little room to doubt that in course of time the clays of North Dakota will become the source of industries that will play no small part in the general development and growth of the commonwealth.

The importance of the clay industry in several foreign countries is somewhat known, but few who have not investigated the subject realize the magnitude of this business. Several years ago, in one of the shires of England, in Staffordshire alone, it is said that over 100,000 operatives were employed in connection with the clay industry. Likewise in Germany and France, in China and Japan, this is an industry of great importance. In the United States, in those of the older states that possess rich deposits of clay, there has already sprung up a flourishing business in the manufacture of a variety of clay wares. This is especially noticeable in New Jersey and Ohio. The total value of the articles manufactured from clay annually, in the United States, is probably from $75,000,000 to $125,000,000 or more.

North Dakota possesses at least two advantages, namely, location and fuel supply, which would aid greatly in successfully establishing a large clay industry in the state. Its situation is such, with reference to deposits of fine clays in other localities that it would naturally have a large supporting territory. The use of the coal found in such abundance in the close proximity to the finer clays, would doubtless be a great help in keeping down the cost of manufacture.

The advantage to the state would be those always secured by the introduction of factories into an agricultural community. New industries develop resources before unused, keep at home as well as bring in a large amount of wealth, enlarge the demand for other products, foster other industries, and in many ways add to the general prosperity.

Although the results of these investigations are encouraging, it is not expected that a great industry of this kind will be at once established. That requires time. It is hoped, however, that the value of these clay resources will be appreciated, and that eventually the clays of the state will be extensively used. To this end it is hoped that these investigations may be helpful.

ANALYSES OF NORTH DAKOTA CLAYS.

CONSTITUENTS.	Dickinson.	Dickinson.	Dickinson.	Dickinson.	Mercer County.	Minot: blue.	Minot: black (under coal.)	Bismarck.	At Lehigh Coal Mine, near Dickinson (over coal.)	At Lehigh Coal Mine, near Dickinson (under coal.)	Williston.	Grand Forks—Brick clay used at the Alsip works.
Silicon	72.66	64.84	64.22	56.03	60.79	56.86	53.72	58.73	55.77	71.25	57.80	51.27
Aluminum (Al_2O_3)	17.33	24.31	?17.22	24.23	16.23	25.03	17.78	14.98	12.15	21.94	9.47	9.33
Iron (Fe_2O_3)	1.05	1.60	2.09	9.46	4.49	6.11	3.85	5.63	4.27	3.67	3.16	3.52
Calcium (CaO)	0.13	0.11	trace	....	0.65	0.71	0.81	2.10	5.92	0.74	7.91	11.15
Magnesium (MgO)	....	0.24	0.37	0.31	1.02	0.76	0.50	0.74	1.90	0.83	2.84	2.31
Potassium (K_2O)	0.36	trace	0.21	0.088	0.19	0.50	0.28	0.16	0.256			0.50
Sodium (Na_2O)	0.38	0.32	0.34	0.72	0.28	0.016	1.72	0.988	0.992			2.08
Water and volatile matter	9.35	*8.58	10.29	9.39	*16.35	*10.014	21.82	16.672	*18.742			
Other matter and errata	....	....	....	....	....	....	....	....	....			....

*By subtraction.

COAL.

THE GEOLOGY.

The existence of extensive beds of coal in North Dakota has been known for some time. New finds are continually extending the known area of coal deposit, and still there is undoubtedly a vast extent of coal in North Dakota not yet absolutely known. Indeed, the coals of that part of the continent lying west of the Missouri river are only just beginning to attract the attention they deserve. It is quite probable that the coal deposits of North Dakota are of the eastern flank of the Rocky Mountain coal range, which has been followed over 500 miles north and south. Whether the outcrops discovered are fragments of one large coal basin, which has been broken up by water action and upheavals, or covered with newer formations, or whether they are the deposits of numerous woody swamps of the same geological period, we may not determine. But it will suffice to say that North Dakota alone has, without doubt, enough coal to supply herself and the less fortunate neighboring states for years, probably centuries, to come.

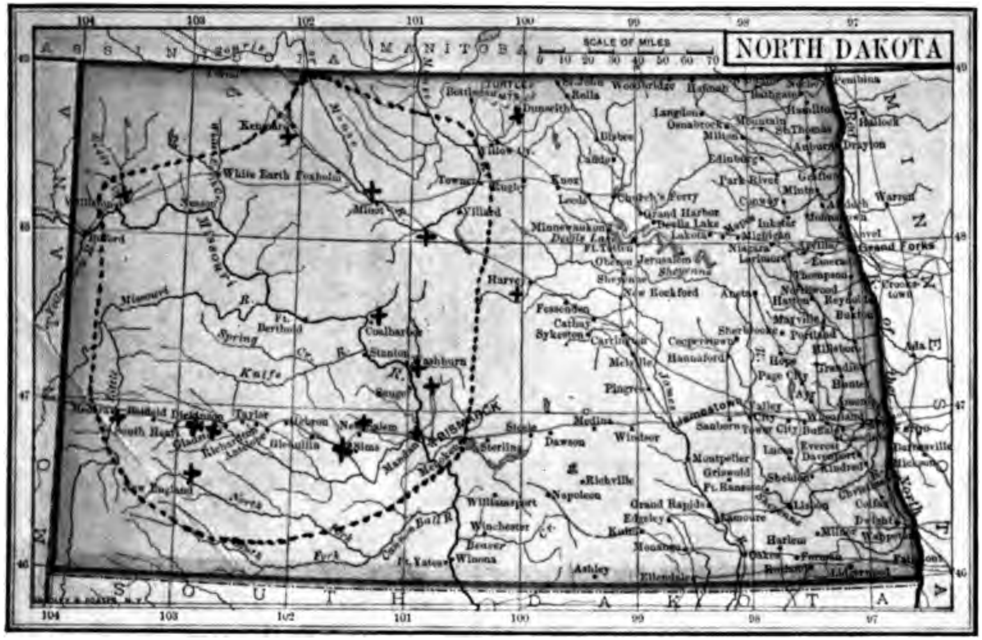
The geology of American coal may be summarized as follows:

Carboniferous, to which belong anthracite and eastern bituminous region. The principal deposits, both as regards extent and quality, embrace the Appalachian, Central, West Central, and Michigan district.

Jura-Triassic, which is of but small area.

Cretaceous and *Tertiary,* which cover a large area, and embrace the Western Plains, Rocky Mountains, Mt. Diablo, and Washington systems, etc. It is to this last group that Dakota coal belongs.

The geology of the coal of the Carboniferous and the Jura-Triassic periods is undisputed. But that of the Western Plains, Rocky Mountains, etc., is involved in much doubt. It has been by some held to be Cretaceous; by others of Eocene; and still others of Miocene-Tertiary origin. So far the paleontology shows the fauna to be allied to the Cretaceous, while the flora is nearer Eocene or Miocene. Dr. Le Conte thinks the coal beds of this area mark the transition between the Createous and the Eocene; that "while it was depositing, the changes of physical geopraphy and climate which closed the Cretaceous and inaugurated the Tertiary had already been accomplished; but Cretaceous types still lingered, ready to disappear. In this group, therefore, Cretaceous and Tertiary forms are more or less mingled; and thus the newly formed land would be covered with Tertiary vegetation, while the Cretaceous animals would hold



COAL DEPOSITS IN NORTH DAKOTA.

...... Within the area marked with the dotted lines coal may be found.

X Coal is mined at the places marked X.

out for awhile. The fossils, so far as I am aware, are almost exclusively plant forms, and those, too, resembling much the varieties now existing, and doubtless are of Tertiary origin. So the geology of Dakota coal is not exactly fixed; but the deposits, I am inclined to think, belong to the Tertiary, or perhaps more properly to the Laramie transition period.

MODE OF OCCURRENCE.

The general direction of the coal deposit in North Dakota seems to be north and south. The seams generally outcrop along the banks of streams or on the side of the bluffs leading to a valley, the direction of which they follow. There may have been a general continuity of deposit, but it seems more likely that these different deposits were made in so many elevated Tertiary marshes. In general it may be said that there are three seams distinctly noticeable, indicating a longer or shorter period of deposition, or a greater or less activity in vegetable growth, corresponding in each case to the thickness of the deposit. These three seams are not always found, but usually at least traces of the three may be discovered. In some cases there are more than this, but those above and below are very thin. The lower of the three seams is the one generally worked, and it appears from 50 to 200 feet below the surface. It varies in thickness from 7 to 20 feet. It is underlain by clay which, in some mines partakes of a fire clay nature but is usually too strongly impregnated with iron and alkalies to be a valuable fire material. From 15 to 25 feet above the lower seam is another, one and one-half to three feet thick. The formation between this and the lower seam is principally of clay, with a layer of sand in some cases. From 15 to 30 feet above this is a third seam of from one to two feet in thickness. This is the uppermost, and is covered with clay, sand or gravel, clay and soil which frequently bears drift boulders. This layer is usually from 10 to 60 feet below the surface, but in some cases it appears to have been entirely washed out.

There are indications of one or more layers below the one generally worked. If a seam of workable thickness should be discovered lower, it would doubtless be more valuable, for the quality improves with the depth of deposit.

It is not to be expected that anthracite coal will be found in North Dakota, even though deeper seams be discovered. The geology of the country will afford nothing better than a high grade lignite or semi-bitumenous variety. It is well agreed that the anthracite varieties are associated with folding and metamorphism of the strata. "In Pennsylvania, in the strongly folded and highly metamorphic eastern portion of the field the coal is anthracitic; while, as we go westward, and the rocks are less and less metamorphic, we find the coal to be more and more bituminous, until, where the rocks are horizontal and unchanged, the coal is always highly bituminous. The same has been observed in Wales; anthracite is always found

in metamorphic regions, and the coal is more and more bituminous as the rocks are less and less metamorphic."—*Le Conte.*

So far as I am aware there is no considerable dip of strata in the coal districts of North Dakota, save in exceptional cases; for example, in the Turtle mountains. So there cannot be expected more than the usual improvement in quality into high grade lignite which increase in depth of deposit might make.

Numerous rumors of oil have been afloat, but I have not been able to see any indications of such, nor could one reasonably expect oil in a district with such formations and physiography.

VARIETIES AND CHARACTERISTICS.

The coal varies somewhat in its physical as well as its chemical properties in different localities. In most cases the cleavage planes correspond to the planes of lamination and are parallel. All samples have a general appearance btween that of cannel and true lignite, and are more or less friable when exposed to the action of air and water. Occasionally samples taken from different mines are found to approach, in physical appearance, a true bituminous coal.

A decided difference is noticed in the physical features of different seams. The upper one or ones, which are too thin to be worked, are more strikingly lignitic, being of a brownish color, of more woody structure and more friable; while the lower seams are of a deeper black color, harder, more compact and less friable. There is a great improvement in the quality as the depth at which the coal is found increases.

It may be helpful to notice a few general points as to the classification of coals before proceeding with the analysis.

The variety of coal depends mainly upon the purity, and the proportion of fixed carbon and volatile matter. Coal consists chiefly of organic matter, but contains varying proportions of inorganic or incombustible substances, which were originally in the sap and framework of the plant, or which were carried in as foreign material during the period of deposition. When coal is burned, the organic combustible matter is consumed and passes away as gas, while the inorganic part is left behind as ash. The relative proportion of the ash determines largely the purity. We may have a coal of 1 or 2 per cent. ash. If no more than 5 per cent. is ash, then we may consider the coal quite free from foreign impurities. We may have coal of 10, 15, 20, or even 30 or 40, per cent. ash. If more than 10 per cent. ash is found, the coal is impure; that is, mixed with foreign matter, which is generally in the form of clay which has infiltered during or after the accumulation of the coal. The most important of the other impurities existing in coals is sulphur. It is objectionable for almost every purpose for which the coal may be used. In heating stoves it tends to lessen the heat and gives off obnoxious gases; it corrodes grates and flues; if used in iron smelting, it degrades the iron; and in gas making it is harmful. If an excessive amount of sulphur is present it is usually as pyrites of iron.

The combustible matter of coal is partly fixed (not easily driven off as gas) and partly volatile (easily converted into gas). When coal contains from 90 to 95 per cent. fixed carbon, it is classed as anthracite. If the combustible matter contains from 80 to 85 per cent. fixed carbon, it becomes semi-anthracite. These are especially good for the rapid generation of steam for locomotive boilers and the like, and hence are sometimes called steam coals. If there is from 60 to 80 per cent. fixed carbon, we have the ordinary bituminous coal. If the fixed carbon runs below 50 per cent. and the volatile matter runs to 50 per cent. or more, we get the highly bituminous fusing coal. This variety is often especially well adapted for gas and coke manufacture, while a still less per cent. of fixed carbon gives us true lignite, then peat, and finally wood.

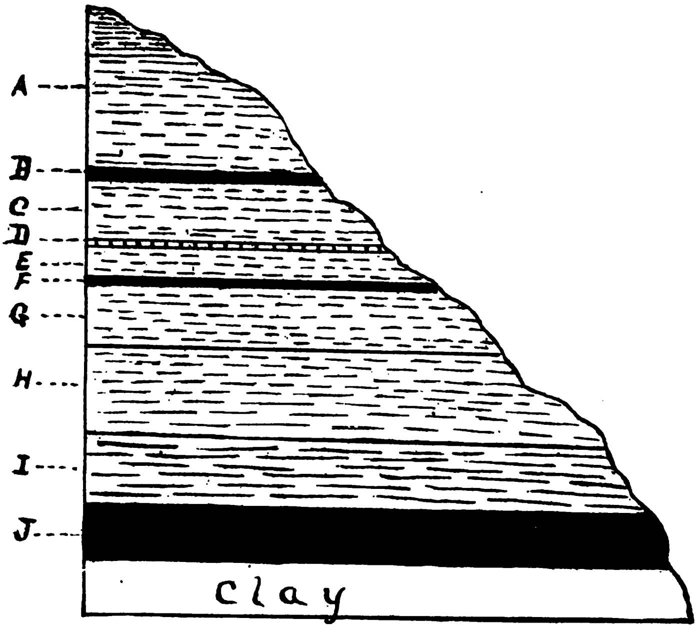
LOCAL DESCRIPTIONS AND ANALYSES.

A few miles northwest of Minot, Ward county, coal is found outcropping along the edge of the bluffs that rise from the valley of the Souris river to the prairie. Coal has been dug from several openings on either side of the valley. Indications are that coal is quite continuous along the banks of this stream for some distance. Some of the old mines, formerly known as the Foote, Colton, and North Dakota Coal Mining Company's mines, and located in this vicinity, are not now worked to any extent.

The Mouse River Lignite Coal Company has opened an extensive mine at Davis near Burlington, Ward county, on the "Soo" railway, about six miles north of Minot. The coal outcrops along the hillside from 60 to 150 feet below the surface. Tunnels have been run in from the side for a distance of about 2,000 feet. There are two openings with about 50 feet of coal left between them. After striking the coal, the tunnel follows the vein. This has an average dip of about two feet to 100 feet away from the entry, but this is not a uniform variation. The layer of coal used is about 1,540 feet above sea level; it is from 9 to 13 feet thick and almost solid, there being only a very thin layer of clay within this coal body. It is uncertain as to whether or not there are layers below the one worked, but there are two thin ones above, each about a foot thick.

This mine is systematically worked and has a large output. Compressed air coal cutters are employed, a fan system provides good ventilation, and the coal is removed by cable cars which run to loading chutes delivering the coal directly into the railway cars. From 60 to 100 men are employed.

The accompanying design will illustrate the formation at this mine. Analyses from several parts of the coal vein are also given.



MOUSE RIVER LIGNITE COAL COMPANY'S MINE,

A—Prairie boulders, sand and yellow clay, 30 to 60 feet.
B—Coal, one foot.
C—Sand and clay, } about 20 feet.
D—Sandstone, } about 20 feet.
E—Sand and clay, } about 20 feet.
F—Coal, one and one-half feet.
G—Sand and yellow clay, about 15 feet.
H—Gray clay, 20 feet.
I—Blue clay, 15 feet.
J—Coal, 10 feet.

No. 1. From bottom of layer.*

Volatile matter, per cent	34.79
Fixed carbon	56.02
Ash	9.19

No. 2. From 18 inches above bottom of layer.

Volatile matter, per cent	37.00
Fixed carbon	55.18
Ash	7.82

No. 3. From center of layer.

Volatile matter, per cent	32.72
Fixed carbon	52.21
Ash	15.07

MOUSE RIVER LIGNITE COAL CO.'S MINE.

No. 4. From portion of layer left for roof.

Volatile matter, per cent..	29.69
Fixed carbon..	44.20
Ash..	26.11

Analysis of two samples from the mine formerly known as North Dakota Coal Mining Company, Minot, N. D.:

No. 6.

Water and volatile matter, per cent.*	55.22
Fixed carbon..	39.66
Ash	5.12

No. 7.

Water and volatile matter, per cent..	53.41
Fixed carbon..	41.09
Ash..	5.50
Sulphur..	.25

COLTON MINE.

This mine is located in the valley of the Souris river, near Burlington, Ward county, on the "Soo rialway. The diagram given above well represents the formation at the Colton mine. This mine is quite well started. Horizontal shafts run from the entrance probably 200 to 300 feet under the hill.

Analyses of two samples of coal from the Colton mine are as follows:

No. 8. From Minot, Colton mine.

Water and volatile matter (not dry), per cent..	52.25
Fixed carbon..	42.62
Ash..	6.13

No. 9. Location same as above.

Water and volatile matter (not dry), per cent..	42.50
Fixed carbon..	48.85
Ash..	8.65
Sulphur..	.06

KENMARE COAL.

Near Kenmare, Ward county, along the line of the "Soo" railway, and about 25 miles from the Canadian boundary, there are several deposits of coal which have been developed to a greater or less extent. The People's Kenmare Dry Coal Company have begun the development of a mine situated about two miles north of the town at the foot of the upper Lake Des Lacs. This coal probably lies at a

*Note.—Wherever the analysis reads "volatile matter" the coal was dried at 100 degrees C. before being analyzed. All which read thus were analyzed within the last three months. Wherever the analysis reads "water and volatile matter" the coals were kept for several weeks in a dry room before analyzing, so that most of the moisture was out of them. Those which read in this way are old analyses.

considerably higher altitude than that at Burlington. The railroad passes directly by the mouth of the tunnel.

The coal outcrops along the hillside in very much the same manner that it does near Minot. At this place the coal appears from 2 to 4 feet above the surface of the lake. The entrance is begun some distance above and is carried on the incline until it intersects the coal vein, which it then follows. There does not seem to be much dip to the coal but it evidently thickens as it extends beneath the hill. Near the entrance the coal is covered with from 40 to 70 feet of sand and clay. As the tunnel is carried farther the covering will increase until it may reach 150 feet.

Numerous borings have been made over the property of the company and these indicate a deposit of large area. The vein now appears to be 6 feet or more in thickness. It is very continuous and shows but slight traces of clay within the layers. It is of good color and quite compact. There is a marked difference in the coal at different points vertically within the vein. Two or three thin layers are much harder and brigher than the main body of the coal. The most noticeable of these appears near the top of the coal body. The variation in composition may be seen by reference to the analyses. This harder layer stands exposure to wind and rain with much less slacking than the average coal from this tunnel.

This company has also begun the manufacture of common brick by the so-called mud process. For this a sandy surface clay is used.

The following are analyses of coal from this mine:

No. 10. From top layer.

Volatile matter, per cent	37.96
Fixer carbon	58.83
Ash	5.21

No. 11. From center.

Volatile matter, per cent	34.95
Fixed carbon	58.01
Ash	7.04

No. 12. From center.

Volatile matter, per cent	34.26
Fixed carbon	57.85
Ash	7.89

No. 13. From bottom.

Volatile matter, per cent	37.52
Fixed carbon	55.28
Ash	7.20

At Kenmare the mine known as the Smith mine is nearly directly across the lake from the People's Kenmare Dry Coal Company's mine. The formations at the two mines are evidently practically the same, therefore no special description will be needed here.

There are one or two other mines operated in this vicinity but they were not visited by the writer.

The following are analyses of coal given to the writer as samples from the Smith mine.

No. 14. From Smith mine.

Volatile matter, per cent	40.59
Fixed carbon	53.24
Ash	6.17

No. 15. From Smith mine.

Volatile matter, per cent	43.57
Fixed carbon	44.49
Ash	11.94

WILLISTON, BUFORD COUNTY.

Going west from Minot coal again appears in the western part of Flannery county and in Buford county. About Williston there is a considerable deposit. This village is located near the banks of the Missouri river. Numerous valleys make back from the river through a rolling prairie. The hillocks and knobs along the valleys vary from rolls to elevations of 200 feet or more. They are for the most part of clay and sand and gravel, covered with a black soil six inches to ten inches in depth, over which boulders are here and there scattered. It is along these ridges that coal is found. There are outcrops, I am told, north, east and southwest of Williston. None of these deposits are worked to any extent, though they are used for the local fuel supply.

The following are analyses of samples of coal from mines near Williston:

No. 16. From Brown & French mine.

Volatile matter	43.98
Fixed carbon	51.80
Ash	4.22

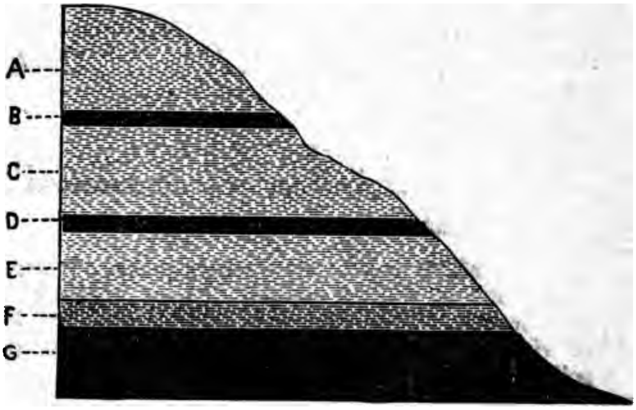
No. 17. From Dahl mine.

Volatile matter	42.65
Fixed carbon	52.78
Ash	4.57

No. 18. From four miles northeast of Williston.

Volatile matter	37.52
Fixed carbon	55.28
Ash	7.20

A section showing the formation in the old Taylor mine is here given:



SECTION FROM THE OLD TAYLOR MINE, WILLISTON, N. D.

A—About 20 feet clay, gravel, etc.
B—About one foot coal.
C—About 20 foot clay.
D—About one foot to one and one-half feet coal.
E—About ten feet clay, etc.
F—About two feet fine, compact clay.
G—About five to seven feet coal.

Analyses of two samples of coal from this mine gave:

No. 19. From the old Taylor mine, Williston, N. D.

Water and volatile matter (not dry), per cent	51.59
Fixed carbon	43.99
Ash	4.42
Sulphur	0.17

No. 20. Location same as above.

Water and volatile matter (not dry), per cent	52.23
Fixed carbon	43.76
Ash	4.01

Almost directly south of Williston, near Medora, Billings county, on the Northern Pacifis railway, coal is seen in two or three thin layers. Although I have no knowledge of a deposit of any considerable thickness, I am informed that there are in this vicinity some very thick deposits of lignite. I have no doubt but this is the case. The region is a remarkably interesting one. It is on the border of the Bad Lands. In many places fire has burned out the coal and baked the clay into a sort of brick rock, sometimes resembling scoria, which covers many hillsides. Water has washed away the yielding clay and left deep gorges and thousands of steep hillocks of fantastic shapes

DICKINSON COAL.

Forty or 50 miles east of Medora we again begin to see outcrops of coal. About one-half mile east of Dickinson, on Mr. Lenneiville's place, coal is gotten for private use by digging into the side hill. This deposit is not developed, being only surface worked. The coal seam is about 10 feet thick, covered with 20 or more feet of clay, etc.

An analysis of a sample of this coal is as follows:

No. 21. From Mr. Lenneiville, Dickinson, N. D.

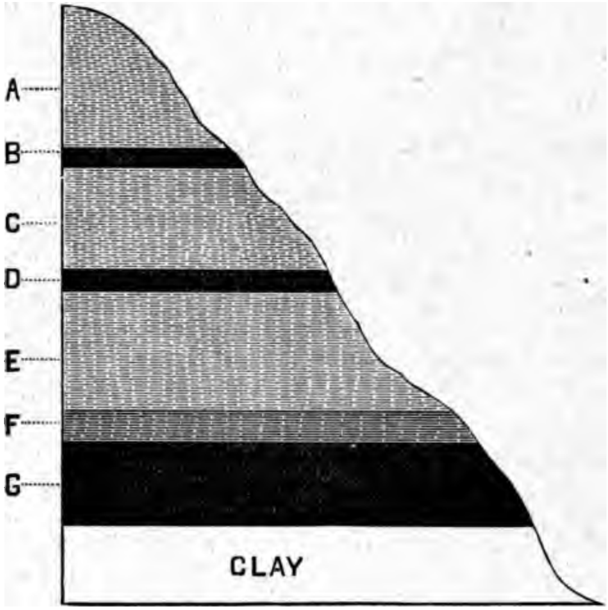
Water and volatile matter (not dry), per cent..	52.59
Fixed carbon	43.02
Ash..	5.39

Near the Dickinson Fire & Pressed Brick Company's plant, on their clay land, an excellent vein of coal is found. The outcrop which simply shows on the north bank of the Heart river, has been tunneled into and has developed into a vein of about 8 feet in thickness. This coal is underlain by the usual gray clay. Over the coal are several grades of clay, ranging in color from gray to yellow and from an exceedingly fine plastic to a rather sandy, yellow clay. A large amount of this coal has been used by the company for steam production and for the brick kilns. No analyses are at hand but it appears to be of about the same quality as that on the Lenneiville place.

LEHIGH.

Four or five miles east of Dickinson is the Lehigh mine, owned by the Consolidated Coal Company. Here coal appears along a little valley from 100 to 200 feet below the surrounding prairie, and is mined by tunneling into the side hill. The seam worked is from 10 to 15 feet in thickness. Above this may be found one of two thin layers. This mine seems well located and is quite extensively worked. The supply is doubtless large. The coal is reached as usual by horizontal tunnels run in from the side of the hill.

The following section may give an idea of the formation:



A—About 25 feet clay and gravel.
B—About one foot of coal.
C—About 25 feet of clay, etc.
D—About two feet of coal.
E—About 30 feet of clay, etc.
F—About three to five feet of compact (gray) clay.
G—About 10 to 15 feet of coal.

The following are analyses of samples of this coal:

No. 22. Bottom of layer.

Volatile matter	42.63
Fixed carbon	49.22
Ash	8.14

No. 23. Two feet from bottom of layer.

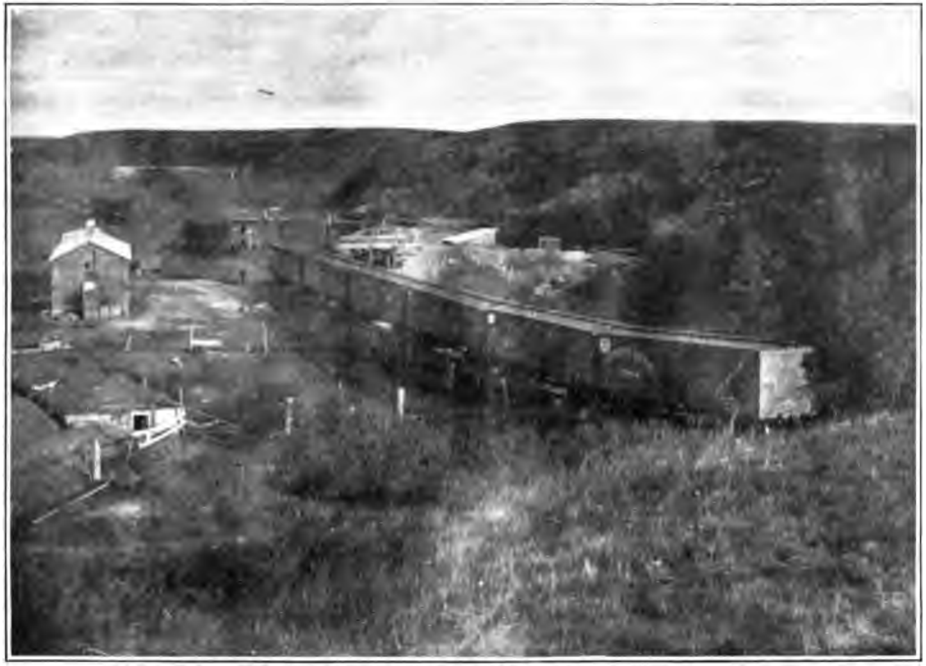
Volatile matter	43.57
Fixed carbon	46.50
Ash	9.93

No. 24. Three feet from bottom of layer.

Volatile matter, per cent	39.99
Fixed carbon	51.60
Ash	8.41

No. 25. Four feet from bottom of layer.

Volatile matter, per cent	40.87
Fixed carbon	48.24
Ash	10.89



CONSOLIDATED COAL COMPANY'S MINE.

No. 26. Five feet from bottom of layer.

Volatile matter, per cent	44.32
Fixed carbon	48.53
Ash	7.15

No. 27. Six feet from bottom of layer.

Volatile matter, per cent	41.59
Fixed carbon	51.80
Ash	6.61

No. 28. Seven and one-half feet from bottom of layer.

Volatile matter, per cent	40.97
Fixed carbon	51.30
Ash	7.73

No. 29. Outcrop at mouth of tunnel.

Volatile matter, per cent	37.06
Fixer carbon	54.06
Ash	8.88

The two following analyses were made several years ago:

No. 30. Lehigh mine.

Water and volatile matter (not dry), per cent	48.61
Fixed carbon	44.39
Ash	7.00
Sulphur	0.35

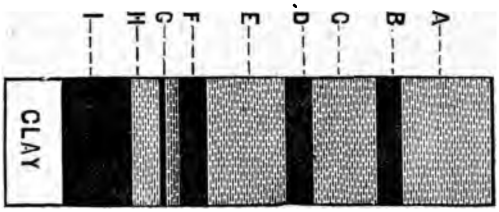
No. 31.

Water and volatile matter (not dry), per cent	52.96
Fixed carbon	41.01
Ash	6.02

SIMS, MORTON COUNTY.

This place is located in a valley perhaps 100 or 200 feet below the level of the prairie. In the banks along the valley from Sims to New Salem, coal is frequently seen. At Sims there are three or four places from which coal has been mined. Samples were secured from what was formerly known as the Sims Mining Company's mine, and from the old North Dakota Coal Mining Company's mine.

The following section will show the formation in this locality:



OLD SIMS MINING COMPANY'S MINE.

A—Clay and gravel
B—Thin layer of coal.
C—Clay and gravel.
D—Coal, one-half foot thick. Probably 30 feet above the thick layer I.
E—Clay.
F—Coal, about one foot thick. Probably 10 feet above the thick layer I.
G—Sand and clay
H—Compact clay.
I—Thick layer of coal—the one worked.

Analyses of two samples from this mine gave the following:

No. 32. From F in section.

Water and volatile matter (not dry), per cent	40.94
Fixed carbon	42.23
Ash	16.83

No. 33. From thick layer I in section.

Water and volatile matter (not dry), per cent	48.62
Fixer carbon	41.31
Ash	10.07
Sulphur	.30

Analyses of two samples from what was formerly known as the North Dakota Coal Mining Company's mine, of the same place, Sims, give the following result:

No. 34. North Dakota Coal Mining Company, Sims, N. D.

Water and volatile matter (not dry), per cent	48.59
Fixed carbon	43.60
Ash	7.81

No. 35. Location same as above.

Water and volatile matter (not dry), per cent	47.20
Fixed carbon	44.58
Ash	8.22
Sulphur	.28

There are several other mines about Sims. At the Wadeson mine an entry has been run for 700 to 800 feet. The coal is about 6 or 7 feet in thickness. It is understood that a compressed air mining machine has been added. At the Burton mine, located about one

AN OUTCROPPING OF COAL ON THE MISSOURI RIVER.

and one-half miles west of Sims, coal is taken from a vein about 8 feet thick. No analyses of coal from these two mines are at hand.

MANDAN.

A sample of coal was given in for analysis, said to have been mined 11 miles north of Mandan, on land belonging to Mr. Blaich. It was simply picked from a surface outcrop.

The analysis is as follows:

No. 36. Mr. Blaich's, near Mandan.

Water and volatile matter (not dry), per cent	49.47
Fixed carbon	43.91
Ash	6.62

WILTON.

Near Wilton, Burleigh county, situated on the line of the Bismarck, Washburn & Great Falls railway, there are several fine deposits of lignite coal. These deposits are usually found under the higher elevations. This region is not nearly so broken as most of those in which lignite coal is found. The prairie is high and rolling. The soil is rich and productive of a strong growth of vegetation. One of the best equipped coal mines in the state is located in this vicinity.

The Washburn mine is about a mile south of the town of Wilton. The entry is made from the prairie level and is run at a sharp incline until the coal vein is reached, which it then follows. Tunnels have been run in this vein for several hundred feet. Six or seven feet of coal is mined and the remaining two feet is left for roof and floor. The coal is underlain by a fine black clay and covered by layers of gray and yellow clay which, toward the surface, becomes mixed with a proportion of fine sand.

This mine is topographically well located. The coal is free from an excess of moisture and is in excellent condition when removed from the deposit. The whole lay-out is carefully planned for convenience and economic operation. An electric power plant has been built and the mine is to be lighted by electricity. The coal is to be worked out by improved electric coal mining machines and the mine cars are removed by an electric cable which takes them to a chute, delivering the coal directly into the freight cars.

Although this mine was but recently started the coal reached is of excellent quality, as may be seen from the analyses given. The coal has been successfully introduced and a considerable demand for it has already developed. It should be said that the samples from which these analyses were made were taken from the first coal mined and before the tunnel had reached far into the vein; doubtless it will improve in quality as the shafts are extended.

No. 37. From Washburn mine.

Volatile matter, per cent	41.10
Fixed carbon	51.87
Ash	7.03

No. 38. From Washburn mine.

Volatile matter, per cent	42.26
Fixed carbon	50.97
Ash	6.77

Several other mines have been opened in the vicinity of Wilton. One of these which has heretofore produced a considerable amount of coal for local consumption is the McClelland mine. The coal in this mine is about 7 feet thick. No analysis has been made by the writer.

The Eckland mine is located about three miles south of the Washburn mine. The surface characteristics and the formations of the two mines are evidently similar. As at the latter mine, the coal is reached from the praire level by an inclined shaft from 150 to 200 feet in length. There is about nine feet of coal, of which seven feet is mined. This coal is of very good quality and locally is used considerably.

Analyses of samples are here given:

No. 39. From Eckland mine; top layer.

Volatile matter, per cent	41.62
Fixed carbon	53.75
Ash	4.63

No. 40. From the Eckland mine; center of layer.

Volatile matter, per cent	40.61
Fixed carbon	53.67
Ash	5.72

No. 41. From the Eckland mine; bottom of layer.

Volatile matter, per cent	42.41
Fixed carbon	50.47
Ash	7.12

WASHBURN, MC LEAN COUNTY.

At several places along the Missouri river 30 or 40 miles above Bismarck, coal is seen to outcrop along the banks of the river and occasionally from the ravines which make into the Missouri. An accompanying cut will show the manner in which it occurs.

The Satterlund mine is about six miles northwest of Washburn. This mine is situated on a coulee leading to the Missouri. The coal is about 9 to 10 feet thick. Of this about 7 feet is mined and the remainder left for roof and floor. The coal is covered with a thick deposit of clay, which is overlaid with 9 to 10 feet of sand, above which is gravel and soil. The tunnel is run in from the side of the bank and follows the vein. It has been extended about 175 to 250 feet. A view of this mine is seen on page —.

The coal has been used successfully for local supply. No analyses have been made by the writer.

One or two other deposits in this region have been opened. The coal vein appears to be of about the same thickness. There is little doubt that the coal underlies a considerable area here.

SHOWING FORMATION AT SATTERLAND'S MINE—(NEAR THE MISSOURI RIVER.)

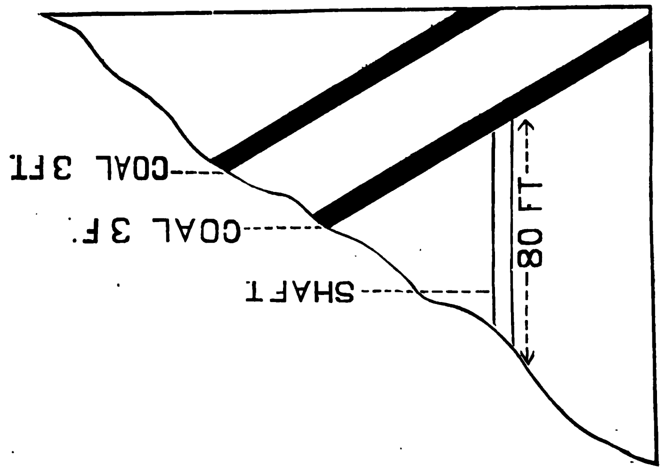
Coal deposits have been opened near Harvey and near Velva, along the "Soo" railway, but they have not been visited by the writer.

TURTLE MOUNTAINS.

Coal again appears in the Turtle mountains. It is quite possible that coal may underlie belts of country extending east and north of Minot and following the Souris river and thence eastward into the Turtle mountain district.

Near Dunseith, Rolette county, coal has been found on the southern slope of the hills. At this place a shaft has been put down 80 feet on the side of the bluff, and a layer of coal three or four feet was struck; below this, on the side hill, an outcrop occurs.

At the time the writer visited the place, the opening to the coal was closed so the nature of the formation and the dip of the deposits could be obtained only from inquiry. The coal of both upper and lower layers seem to have an inclination of about 30 degrees toward the hills. The following will give an idea of the deposit, according to the information given me:



A sample that I picked up from a pile of refuse which had been mined and exposed to the weather for three years gave:

No. 42.

Water and volatile matter, per cent..	44.79
Fixed carbon..	40.56
Ash..	14.65

If the coal layers of this deposit dip in the direction and at the angle stated, it is not strange that such coal or even better should be found. It is, however, quite probable that this inclination does not continue far. There is a possibility that there are layers of coal deeper than those indicated in the diagram. This region, as well as

others, deserves a more thorough investigation than has ever been given it.

The forgoing localities are all that the writer has been able to visit. These are for the most part on or near some line of railroad. All of the deposits mentioned in this report will constitute but a very small portion of the whole coal field of North Dakota. But these will serve to indicate the area in this state over which coal may extend.

The following are analyses of samples sent in from places not already mentioned, and which the writer did not visit in person. These four analyses were made several years ago:

No. 43. Sample received from A. P. Folsom, New England City, Hettinger county, N. D.

Water and volatile matter, per cent	47.62
Fixed carbon	50.67
Ash	1.71
Sulphur	.33

This coal cokes. But it is not a very good coke. Withal, the sample was a very good one. It will be noticed that the ash of this coal is remarkably small.

No. 44. Sent in for analysis by the North Dakota Coal Mining Company, Coal Harbor, McLean county, N. D. (Taken from a depth of 183 feet, and mined for three years.)

Water and volatile matter, per cent	47.27
Fixed carbon	45.77
Ash	6.96
Sulphur	.22

No.. 45 Sample received for analysis from Thos. Dodsworth, Sykeston, N. D. (Sample from Pony Gulch mine, near western border of Wells county.)

Water and volatile matter, per cent	45.75
Fixed carbon	49.03
Ash	5.22

No. 46. Sample sent by Thos. Bartnow. Location, township 147, range 84, section 15. From an 11-foot vein.

Water and volatile matter, per cent	45.89
Fixed carbon	48.47
Ash	5.64

For the purpose of comparison I give below averages of analyses of coal from several well known coal regions.

Average of twenty-six samples of North Dakota coals. (Dried.) See page 79.

Volatile matter, per cent	40.33
Fixed carbon	52.08
Ash	7.59
Average of samples analyzed for per cent. of sulphur	.34

Average of forty-one samples of West Virginia bituminous coals. See page 83.

Volatile matter, per cent	25.17
Fixed carbon	67.16
Ash	7.75

Average of twenty-two samples of Maryland dry, semi-bituminous coals. See page 82.

Volatile matter, per cent	14.66
Fixed carbon	75.99
Ash	8.95

Average of twenty-six samples of dry, close burning, semi-bitüminous coals of Pennsylvania. See page 81.

Volatile matter, per cent	20.77
Fixed carbon	69.97
Ash	12.54

RELATIVE VALUE.

It is evident from the investigations which have been carried on that the heat value or calorific power of the average of the lignite of North Dakota, when entirely dry, is about 80 to 85 per cent. of that of the Hocking Valley coal, and about 68 per cent. of that of the Pocahontas coal. Again, by referring to tables of analyses (on pages 81-83) of some of the best bituminous coals of West Virginia, Maryland and Pennsylvania it will be possible to get approximate fuel values from the proportion of fixed carbon. For general heating purposes under conditions now in common use the coal can usually be estimated approximately by the amount of fixed carbon it contains. By referring to the analyses it will be seen that the fixed carbon in the 26 samples of North Dakota coal (dried) recently analyzed, averages 52.08 per cent.; that of 41 samples of West Virginia bituminous coals, 67.16 per cent.; that of 22 samples of the better grades of semi-bituminous, dry coals of Maryland, 75.99 per cent., and that of 26 samples of the fine, dry, close burning bituminous coals of Pennsylvania, 69.97 per cent. Using this method of determination, the heating power of one ton of North Dakota coal will equal about 76 per cent. of a West Virginia bituminous, 65.9 per cent of Maryland dry coal, semi-bituminous, and 74.4 per cent of Pennsylvania dry, close burning bituminous. By these comparisons it will be seen that North Dakota lignite ranks, so far as its heat producing power is concerned, between the ordinary lignite and a bituminous coal, and that it is far superior to the lignite mined in other countries.

It seems evident to one who has made a study of the problems connected with the use of lignite coal in North Dakota, that this fuel is sure to become the principal source of supply for this state and for portions of adjoining states. "It must always hold true that local supplies of mineral fuels, whatever their quality, must be the chief dependence of communities, because of their proximity to the con-

sumer." Lignites even of inferior quality are coming into increasing use in many countries. It is estimated that in Austria alone the production of lignite during 1896 was over 18,750,000 tons, while during the next year, 1897, it increased over a million and a half tons. North Dakota coal, though lignite, is of a high grade. It may safely be predicted that its use will be extended rapidly.

As compared with wood, there is no doubt that, for ordinary purposes, this coal is far superior at reasonable prices. It is to be hoped that little timber will be burned in North Dakota where so much better and usually cheaper fuel can be secured. In some localities it is sad to notice how much wood is cut for fuel. Every tree should be encouraged to grow. If tree culture were what it should be in North Dakota the good resulting would be of inestimable value.

Lignite coal is not adapted for the manufacture of gas and coke nor for smelting purposes.

For heating locomotive boilers, much of this coal might not be economical for general use since it would perhaps, be difficult to arrange a locomotive grate, draft, etc., suited to other kinds of coal, which would not waste the lignite.

For general manufacturing and heating purposes, in which most of the fuel is used, the coal of North Dakota is well adapted, especially if burned with proper draft or blast arrangement. By the use of native coal, hundreds of thousands of dollars might be kept within the state and encouragement given to the development of an important resource.

POINTS OF ADVANTAGE.

The purity of a fuel is a very important element in determining its value. A difference of 2 or 3 per cent. in the earthy matter of two coals may be the source of a very serious difference in their final value. North Dakota coals are almost always very free from earthy matter as seen from the amount and character of their ash.

"Of all the substances of a hurtful kind commonly to be found in coals, sulphur, usually combined with iron forming minutely disseminated suphuret of iron, is by far the most injurious. The proportions in which it prevails in different coals are various, many beds revealing scarcely a trace, while others again contain as much as 3 or 4, or even 6, per cent. of this deleterious constituent."

From the analyses of Ohio coals, published by Professor Wormley, the average amount of sulphur in 25 samples was 2.04 per cent. Of the coals of Great Britain, an analysis made a few years since for the British Admiralty, the average amount of sulphur in 37 Welsh coals was 1.42 per cent.; of 28 from Lancanshire, 1.42 per cent.; eight Scotch coals, 1.45 per cent.

It will be seen by reference to the analyses of North Dakota coals that the average is .34 per cent. sulphur, while the lowest shows but little more than a trace. This remarkable freedom from sulphur is of no small advantage to any coal.

Another important matter in the economics of coal is the character

of the ash. In many coals a large amount is lost in ash clinkers. For all purposes it is desirable to have a small clinkerless ash. This is especially desirable in certain cases where intense or melting heat is required. A small ash of reasonably white color is a good characteristic. The ash of North Dakota coal seems very free from clinkers, of good color, and is moderately small in amount.

PROPER COMBUSTION.

It is largely due to a lack of familiarity with the character of lignite coal and to a lack of knowledge of the best methods of burning it that so many have not been entirely satisfied in their attempts at using this coal.

Moisture.—A universal mistake is made in burning lignite coal with too large an amount of moisture. This coal needs to be seasoned for some time after it is mined before it is put on the market. The miners could add to the popularity and value of lignite coal more than any other way by mining the coal some time before shipment and storing it under proper shelter to season.

As mined, lignite coal contains all the way from 12 to 29 per cent of moisture. Too often it is dumped directly from the mine car into the freight car which delivers it to the consumer. The presence of 15 to 20 per cent. of moisture reduces enormously the heat value of any coal. The coal looses nothing of value by lying to dry and there will be but slight loss from slacking if properly protected.

Size.—Another cause of difficulty is due to the fact that the lignite is usually sent out in large lumps often times weighing 50 pounds or more. The coal for steam boilers and for stoves is sent out the same size. At the mines the coal should be broken and graded to proper sizes for stove use and for steam boiler use. Most people who use lignite in stoves feed it in too large lumps. They naturally dislike to stop to break up large lumps when they are ready to burn. Experience has convinced the writer that the best size for stoves is that known as egg size. Too large lumps do not give sufficient oxidizing surface and give a too open fire body. A fire box properly filled with the egg size lignite gives a compact body of fire and still presents a very much larger fuel surface. Even for steam boilers the writer believes that most of the lignite is shipped and burned in too large lumps.

Draft.—As has just been said, proper combustion depends largely upon the size of coal which will give an abundant air surface. Besides that, the stove should have a good draft so arranged that the air can be directed up through the burning coal, but so that it can easily be controlled and closely shut down when it is desired to hold the coal at low heat.

Fire Boxes.—The fire box should be kept well filled with coal. Many people fail to get good results because they do not have a sufficient body of coals to keep up complete combustion of the gases.

A large body of coal with drafts regulated as needed will give the most satisfactory results.

Grates should be rather closer than for other coal. This prevents loss from fine, unburned coal dropping through with the ash. If a rocking grate is used (and such a grate is well suited for lignite) it should not be too violently rocked when cleaning, for by so doing some of the coal is lost and the rest is often shaken into too dense a body.

By observing the above precautions the writer has used lignite successfully in a variety of cooking and heating stoves. So far as can easily be estimated, the use of lignite seems to have resulted in a saving over other fuels of from 15 to 40 per cent.

Forced Draft in Boiler and Steam Heating Plants.—Lignite coal can be used with especially fine results in connection with a hot air forced draft system. Such a system gives a uniform and sufficient supply of oxygen for a more nearly perfect combustion with but slight need of disturbing the coal body. The indiscriminate poking and shaking of the coal is a source of much loss of fuel and heat. Some design of fine rocking grate seems best suited to lignite. In cleaning the grate a very slight rocking movement will usually be all that is needed. The poker need seldom be used except for the purpose of distributing the fuel in the fire box.

A pressure regulator is a valuable adjunct to a hot air fan. Such an apparatus reduces the blast automatically when a given pressure of steam is reached and increases the blast when the pressure drops below a given point. These limits can be adjusted by the engineer according to the requirements.

With such an arrangement of grates, blast and regulator the use of lignite, if it is reasonably dry, is a decided success. This is economical, not only as increasing the heating value of the coal, but also in reducing the labor of engineer and fireman and in maintaining a much more uniform temperature. Such blast arrangements have been installed at several plants where lignite is used and in every case the result secured are remarkably satisfactory. This is notably so at the heating plant of the asylum at Jamestown and at the heating and lighting plant of the State University at Grand Forks. A view is given showing the simplicity and compactness of the system used at the University furnaces.

Explanation of figure opposite page —, showing arrangement of hot air blast and regulator system used at the University of North Dakota heating and lighting plant.

"A" is a fan connected by the pipe "B" with the flues which enter the smokestack. This pipe is arranged so as to permit the use of either the flue gases or the hot air which accumulates above the boilers, or a portion of each. The hot air is forced into a tight combustion chamber by passing under the grates at "C." The amount of air admitted can be regulated by checks at "C," as it is also by the regulator "F." This regulator is connected with the

FURNACES USING BLAST AND REGULATOR—(AT UNIVERSITY HEAT AND LIGHT PLANT.)

steam pipe "E" which feeds the steam to engine "D," and is also connected with the water pressure. When the pressure of steam rises above what the scale is set for, the equilibrium is destroyed and the engine running the fan is shut off automatically and at the same time the drafts are closed. It remains so until the pressure reaches the mark set on the scale, or slightly lower, when the steam pressure is too low to balance the weights and the steam valve is gradually opened and the blast turned on. This is all done without the attention of the engineer and gradually, so that the pressure is kept very uniform. This arrangement aids greatly in economizing fuel and labor. The engine is run by exhaust steam. The grates "G" are of the fine, rocking fork pattern, so adjusted as to be easily operated by a lever without opening the doors or disturbing the fire.

Briquetted Lignite.—There can be little doubt but that for general stove and furnace use briquetted lignite would prove a most economical and popular fuel. Coal dust and waste from bituminous and anthracite has for years been successfully briquetted in various parts of Europe. Coal in this form has been well liked because of its fuel value, its cleanliness and its lower cost. In Europe briquetted bituminous coal has been used quite extensively on locomotives and steamships because of its compactness and other properties. It has also been used for manufacturing and domestic purposes. It is there no experiment. Heretofore comparatively little attention has been given to this matter in America. Recently two or three briquetting plants have been projected for the eastern bituminous regions. Lignite, however, presents more serious difficulties to this process than does bituminous coal. For this and other reasons the commercial briquetting of lignite has not been taken up in this country. There is little doubt, however, that within another decade some successful and sufficiently inexpensive method will have been developed and placed in active use in this region. When this is accomplished North Dakota will furnish an enormous supply of excellent fuel.

Pulverized Lignite.—There is, however, little doubt that the most perfect method of combustion of highly gaseous coals is brought about by burning the pulverized material in a draft of air. Such a method has been employed for some years to a limited degree for special technical purposes and in certain industries, but the machinery and appliances required for this method of preparation have hitherto been too extensive and costly to admit of its general adoption in small factories and heating plants. But recently the mechanical devices for pulverizing the coal and producing a blast have been so simplified, combined and reduced in price that it will soon be practical to use this method of feeding fuel to furnaces used in small mills and heating plants. There seems to be no reason why, for such places, this method will not soon come into general use where gaseous coal is burned. By using the fuel in this form conditions are secured very similar to those gotten in the use of crude petroleum or

crude gas. In fact, pulverized gaseous coal fed into a furnace by an air blast is very nearly the same as crude gas used with a blast.

With the heat of the furnace once at the suitable point the relative supply of coal and air can, by means of valves, be regulated so quickly and so perfectly that very nearly complete combustion of the heat producing constituents can be secured. Besides, the fire is very uniform and the feed requires no special fireman, as it is automatic.

The writer is quite familar with this method of burning coal and is fully convinced that its use will be extended rapidly. If dry lignite coal of North Dakota is used in this manner there is no reason why it should not produce, ton per ton compared with the best eastern bituminous coal, a high per cent. of their heating power, for besides the consumption of its fixed carbon this method utilizes nearly all of the volatile gases of high calorific power, a large per cent of which are lost by the ordinary methods of combustion to which lignite is subjected.

GROWTH OF THE INDUSTRY.

From what has been said it may justly be concluded that the coal of North Dakota is of inestimable value to the people of this state. The worth of lignite as a fuel is just beginning to be realized by many, and from this time the development of the industry will doubtless be very marked. By reference to the report of the Hon. H. T. Helgeson, Commissioner of Agriculture and Labor for the year ending 1890, it will be seen that the consumption of the lignite coal of this state has increased enormously during the past ten years. At that time the statistical report showed capital invested amounting to $64,600 and a total annual product of 8,500 tons. At the present time, as nearly as the writer can ascertain, there is from $150,000 to $200,000 capital invested in connection with the coal industry of this state. The annual production is about 100,000 to 125,000 tons. The average annual value of this product is from $175,000 to $225,000. This is a very remarkable development, especially when we consider that a large proportion of the increase has occurred within the last three years. Evidently we are just entering a period which will doubtless show a far more wonderful development of this resource than there has been during the last ten years. Any aid which can be given to this industry will surely be amply rewarded in its growth.

With an increase in population and a better knowledge of the proper methods of use and of the value of lignite coal, this abundant and cheap supply of fuel will aid in bringing in new industries and will furnish supplies of great value to vast regions otherwise scantily provided with fuel.

NORTH DAKOTA LIGNITE COALS.

Analyzed at the chemical laboratory, University of North Dakota, for the state geological survey. Samples gathered and analyzed during the year 1900. Dried before analyzing.

Locality	Name of Mine	Analyses.		
		Carbon	Volatile Matter	Ash
Kenmare	Wright Mine	58.83	37.96	5.21
Kenmare	Wright Mine	58.01	34.95	7.04
Kenmare	Wright Mine	57.85	34.26	7.89
Kenmare	Wright Mine	55.28	37.52	7.20
Kenmare	Smith Mine	53.24	40.59	6.17
Kenmare	Smith Mine	44.49	43.57	11.94
Kenmare	Kraus Mine	48.98	43.63	7.39
Burlington	Mouse River Lignite Coal Co	56.02	34.79	9.19
Burlington	Mouse River Lignite Coal Co	55.18	37.00	7.82
Burlington	Mouse River Lignite Coal Co	52.21	32.72	15.07
Wilton	Washburn Mine	51.87	41.10	7.03
Wilton	Washburn Mine	50.97	42.26	6.77
Wilton	Eckland Mine	53.75	41.62	4.63
Wilton	Eckland Mine	53.67	40.61	5.72
Wilton	Eckland Mine	50.47	42.41	7.12
Lehigh	Lehigh Mine	49.22	42.63	8.14
Lehigh	Lehigh Mine	46.50	43.57	9.93
Lehigh	Lehigh Mine	51.60	39.99	8.41
Lehigh	Lehigh Mine	48.24	40.87	10.89
Lehigh	Lehigh Mine	48.53	44.32	7.15
Lehigh	Lehigh Mine	51.80	41.59	6.61
Lehigh	Lehigh Mine	51.30	40.97	7.73
Lehigh	Lehigh Mine	54.06	37.06	8.88
Near Williston	Brown & French Mine	51.80	43.98	4.22
Near Williston	Dahl Mine	52.78	42.65	4.57
Near Williston		49.73	43.98	6.29
Average of the 26 samples		52.08	40.33	7.59

NORTH DAKOTA LIGNITE COALS.

Analyzed at the chemical laboratory, University of North Dakota, for the state geological survey. Analyses made several years ago. Some moisture calculated with volatile matter.

Locality	Name of Mine	Analyses		
		Carbon	Volatile Matter	Ash
Minot	North Dakota Coal Mining Co.	39.66	55.22	5.1
Minot	North Dakota Coal Mining Co.	41 09	53.41	5.50
Minot	Colton mine	41.62	52.25	6.13
Minot	Colton mine	48.85	42.50	8.65
Williston	Taylor mine	43.99	51.59	4 42
Williston	Taylor mine	43.76	52.23	4.01
Dickinson	Mr. Lenneiville's	43.02	52.59	5.39
Dickinson	Lehigh mine	44.39	48 61	7.00
Dickinson	Lehigh mine	41.01	52.96	6.02
Sims	Sims' Mining Co.'s mine	42 23	40.94	16.83
Sims	Sims' Mining Co.s' mine	41.31	48.62	10.07
Sims	N. D. Coal Mining Co.'s mine	43.60	48.59	7.81
Sims	N. D. Coal Mining Co.s' mine	44.58	47.20	8.22
Mandan	Mr. Blaichs'	43.91	49.47	6.62
Dunseith		40.56	44.79	14.65
New England City		50.67	47 62	1.71
Coal Harbor	North Dakota Coal Mining Co.	45.77	47.27	6.96
Wells County	Pony Gulch mine	49.03	45.75	5.22
Coal Harbor		48 47	45.89	5.64
Average of the 19 samples		44.08	48.79	7.15

MODERATELY BITUMINOUS, DRY AND CLOSE BURNING COALS IN PENNSYLVANIA.

County or District	Locality	By Whom Analyzed	Analyses: Carbon	Analyses: Volatile Matter	Analyses: Ash
Tioga or Blossburg coal field	Blossburg	Taylor and Clemson	75.40	16.40	8.20
	Blossburg, Bear Creek	Taylor and Clemson	73 74	15.00	11.26
	Blossburg	Taylor and Clemson	73.00	15.60	11.40
	Blossburg	State report	62.80	32.80	5 20
	Blossburg, Johnson's Run	Taylor and Clemson	69.30	14.60	16.10
	Arbon Company	W. R. Johnson	73 11	16.12	10.77
Ralston and Lycoming Creek District	Ralston	State report	74.50	20.50	5.00
	Ralston	W. R. Johnson	71.54	14.50	13.96
	Queen's Run (average of 40 specimens)	W. R. Johnson	73.44	18.81	7.75
	Queen's Run	State report	73.68	21 50	4 60
Bradford or Towanda coal field	Schroeder, branch of Towanda creek	W. R. Johnson	62.60	15.00	22.40
		W. R. Johnson	70.00	17.40	12.60
		W. R. Johnson	63.90	19.10	17.00
	Schroeder, branch of Towanda creek	W. R. Johnson	68.10	20 50	11.40
			65 50	19 20	15.30
			74 97	19.30	5.73
Center county	Snow-shoe	State report	76.73	21.20	2 07
Center county	Lick Run	State report	66.21	20.72	13.07
Clearfield county	Karthus	W. R. Johnson	68.15	26.80	5.05
Clearfield countk	Karthus	W. R. Johnson	80.49	12.83	6.68
Clearfield county	Karthus	W. R. Johnson	76.64	22.27	5.09
Clearfield county	Karthus	State report	78·20	13.00	8 80
Clearfield county	Karthus	State report	70.50	24.80	4.70
Clearfield county	Curwensville	State report	67.70	27.00	5.30
Clearfield county	Caledonia	State report	54.50	37 00	8 50
Clearfield county	Caledonia	State report	54.60	38.20	2.70
Average of the 26 analyses			69.97	20.77	12 54

SEMI-BITUMINOUS OR DRY COALS IN THE STATE OF MARYLAND.

County	Locality	By Whom Analyzed	Analyses		
			Carbon	Volatile Matter	Ash
Alleghany	Maryland Company	Silliman and Shepard	82.01	15.00	2.99
Alleghany	Cumberland coal	W. Hayes (Boston)	77.86	15.60	6.54
Alleghany	Savage River	Dr. Jones (Washington)	78.00	19.00	3 00
Alleghany	Savage River	D. Jackson (Boston)	77.09	16 05	7.06
Alleghany	Maryland Company	Dr. Jones (Washington)	72.50	22.50	5.30
Alleghany	Maryland Company	Dr. Jones (Washington)	81.00	15.00	4.00
Alleghany	Maryland Company	Dr. Ducatel	70.00	20.57	9.50
Alleghany	Dan's Mount	Johnson	73.59	16.04	10.37
Alleghany	Cumberland coal	Prof. Daniel	66.30	19.40	14.30
Alleghany	Cumberland coal	Johnson	67.26	14 42	18.32
Alleghany	Cumberland coal	Johnson	74.53	15.13	10.34
Alleghany	Cumberland coal	Silliman	76.77	14 66	8.57
Alleghany	Cumberland coal	Prof. Renwick	81 00	13.00	6.00
Alleghany	Cumberland coal	Johnson	77.25	16.23	6.52
Alleghany	Lonaconing Company	Johnson	70.75	16.03	13 22
Alleghany	Maryland Company	Johnson	68.56	15.62	15.82
Alleghany	Frostburg	Chilton	77.00	12.00	11.00
Alleghany	Frostburg (mean of 2 analyses)	Dr. J. Percy	78.80	9.47	11.73
Alleghany	Big vein (mean of 5 analyses)	Dr. Higgins	88.05	8.54	3.41
Alleghany	6 ft. vein (mean of 5 analyses)	Dr. Higgins	86.01	8.68	5.31
Alleghany	44 in. vein (mean of 5 analyses)	Dr. Higgins	74.24	7.13	18.63
Alleghany	Oakland (mean of 5 analyses)	Dr. H ins	73.34	12.54	5.12
Average of the 22 analyses			75.99	14.66	8.95

MODERATELY BITUMINOUS COALS IN WEST VIRGINIA.

County		Locality	By Whom Analyzed	Analyses: Carbon	Analyses: Volatile Matter	Analyses: Ash
Lower coal series in Valley of the Kanawha		D. Ruffners' bank	W. B. Roger's state report.	57.28	35 08	7.64
		Warth's bank	"	54.00	39 76	6.24
Semi-bituminous or dry.	Montgomery	Thom's creek	W. B. Rogers	80.20	13 60	6.20
Semi-bituminous or dry.	Montgomery	Lewisburg	"	78.84	14 16	7 00
Boutetourt		Catawba	"	78.50	16 50	5.00
Hampshire and Hardy Counties—Basins containing the lower coal series.	Hampshire	Brantzburg, N. Br. Potomac	"	72.40	19.72	7.88
	Hampshire	Oliver's tract	"	79.08	16.28	4.64
	Hampshire	Nr. Westernport	"	82.60	15.76	2.64
	Maryland	Lanaconing	"	77.43	19.37	3.20
	Maryland	Abraham's creek	"	74.00	18.60	7.40
	Maryland	1 mile from top of Alleghany	"	77.12	19.60	3 28
	Maryland	Vandover's	"	61 44	14.28	24.28
	Hardy	Kitzmiller's	"	79.76	15.48	4.76
	Hardy	Falls of Stony river	"	79.16	15.52	5.32
	Hardy	Abraham's creek	"	72.40	15.20	12.40
	Hardy	Stony river	"	83 36	13 28	3.36
	Hardy	Michaels'	"	45.24	14.96	39.80
Preston and Mongalia Counties — Basins containing the lower coal series.	Preston	Kingswood	State reports	53.77	31.75	14 48
	Preston	Kingswood	"	65.32	27.77	6.91
	Preston	Kingswood	"	73 68	21 00	5.32
	Preston	Deck Hollow, c.	"	65.42	23.42	11.16
	Preston	Buffalo Leech Run	"	62 56.	29.60	7.84
	Preston	Big Sandy	"	67.60	22 40	10.00
	Preston	N. Brandonville	"	65.28	30.80	3.92
	Preston	Cheat river near Kingswood	"	60.36	25.00	14 64
	Preston	Big Sandy, w. side	"	66.64	27.12	6.24
	Preston	Kingswood	"	68.32	26 48	5.20
	Preston	Kingswood	"	67.28	29.68	3 04
	Preston	Big Sandy basin	"	60.04	26.88	13.08
	Preston	Kingswood	"	64.24	30.24	5.32
South side of James river		Stonehenge	"	58.70	36.50	4.80
Bituminous coals in Eastern Virginia, in the Chesterfield, Powhattan, Goochland and Henrica basins.	Chesterfield	Maidenhead	"	63.97	32 83	3.20
	Chesterfield	Heth's pit	"	62 35	37.65	2.80
	Chesterfield	Mills' and Reid's	"	57.80	38.60	3.60
	Chesterfield	Will's pit	"	62 90	32 50	4.60
	Chesterfield	Green hole shaft	"	67.83	30 17	2.00
	Chesterfield	Heth's deep shaft	"	53.36	35 82	10.82
	Chesterfield	Heth's deep snaft	"	66.50	28.40	5.10
	Chesterfield	Heth's deep shaft	"	61.68	28.80	9.52
	Chesterfield	Pawhattan pits	"	59.87	32.33	7.80
	Chesterfield	Winterpock creek	"	65.52	29.12	5 36
Averages of the 41 analyses				67.16	25.17	7.75

WATER.

The most important point to which attention will be briefly called under this heading is the sanitary condition of wells. This short discussion of well waters must be considered simply as introductory to a more exhaustive report on the water supply to be prepared later.

It is through the indulgence and co-operation of the United States Geological Survey that the writer is permitted to use in this report much data which he has prepared as a portion of a government report on the water supply, which will be published by the United States Geological Survey.

In the early part of this report there is given a brief account of the geology and topography of the state. In the discussion of both of these topics it is impossible to overlook the important influence which the surface and underground water supplies have upon the geology of a region, and as certainly the effect which the geology and topography have upon the water supply. As few outcrops or deep cuts are found over a large portion of the state, especially the central part, our knowledge of the lower formations would be much less certain were it not for artesian well borings and similar evidence.

Starting with the Dakota sandstone, the total thickness of which is not known, the deposit next above is the Benton, composed of dark clays and shales; next is the Pierre, represented by similar shales and clays, and upon the Pierre the drift is spread for a thickness varying from 20 to 50 feet.

The underground water supply of this region is derived from two formations; the deep artesian water comes from the Dakota sandstone, while that of the shallow wells comes chiefly from the till at the top of the Pierre or in the upper layers of the Pierre itself. The artesian water flows with some force, the well at Devils Lake furnishing about 40 gallons per minute. The water commonly carries a small amount of fine Dakota sand and is rather strongly impregnated with salts.

A large number of artesian wells have been bored in the southern and eastern part of North Dakota, but only an occasional well has been attempted in the northwestern portion of the state. In the Red River valley the artesian wells usually give a small flow at 100 to 300 feet below the surface, but most of these wells give little or no pressure. The wells of the south central part of the state, however, all give a large flow at from 400 to 1,200 feet, with a good pressure at the surface. Owing to the small pressure and to the depth of boring required to secure the flow of water it has been

too expensive for individuals to sink artesian wells in the central and western portion of the state.

But it is not the purpose of the writer to take up in this report a discussion of the artesian wells. This source of water supply will be carefully considered in another report. It is to the shallow or common wells that I wish briefly to call attention. The great importance of well waters in this state is not emphasized because of the lack of other water supplies but because of the great abundance of this source of water and the possible advantageous use of it as an artificial source of supply in certain methods of small farming, and as a supply for stock and for household purposes.

From an examination of several hundred wells in the eastern and central portions of the state and from a study of the containing formations and the surrounding topographic and geologic conditions it would appear that there is no need of fear for the permanency of a large supply of subterranean water. In the eastern part of the state water is reached at from 15 to 40 feet, and is found in the glacial or post glacial drift. It is confined by blue and yellow clays. In the central portion of the state the well water is generally derived from the till above the Pierre blue clays or in the top layers of this formation. In places in the western portion of the state water is found lying upon Tertiary formations, generally of gray clay.

The flow of water in most of the wells of the central and eastern portions of the state is very slow because of the compact nature of the strata through which the water must pass. The daily flow of these wells when pumped to their limit may seem small to those accustomed to the rapid flow of artesian wells and of large springs, but the important point is as to the capacity of the underground reservoir.

In considering the use of both artesian and shallow well water the question is frequently asked as to the source and effect of the alkalies and their connection with alkaline spots. The alkaline spots which are occasionally seen on the prairies and alkaline waters are probably in a measure due to the same causes. For hundreds of years before the settlement of the west, prairie fires destroyed the summer's growth of grass, leaving upon the surface the ash or mineral constituents of the vegetation, a large proportion of which was potassium and sodium carbonates. These compounds, being soluble in water, were dissolved by the rain and melting snow and carried to the lower places. During the warm summer much of this water evaporated and there was left an accumulation of the various soluble salts, especially alkaline carbonates. Thus in low places alkaline matter has been accumulating for years, and in this condensed form is very injurious to vegetation. Soil strongly impregnated with alkalies is occasionally found on moderately high land, but this is exceptional and was produced under peculiar circumstances. The water of wells is never so strongly alkaline as the water in these places.

It will be seen from the analyses of many samples of water that

there is not a sufficient quantity of alkalies or mineral salts to do any injury to soil by their presence in water used on vegetation.

The presence of the small amount of alkalies in the well water of these prairies is probably due to the ash of the burned prairie grass, being that portion which was carried down by the imbibition of the soil. Water obtained at or near the top of the Pierre formation is especially liable to be alkaline. This is probably due to the accumulation in and saturation of this compact clay formation with surface water impregnated with these salts in the way just described. As prairie fires cease and the present pernicious practice of burning the straw is done away with the alkaline spots and the alkaline water will doubtless become improved. The free use of the water of shallow wells will greatly tend to reduce the alkalies which these wells contain and thus improve them for drinking purposes.

The limit of the capacity of surface wells in this state cannot be stated, since in but few cases has the flow per hour or day been estimated. Data obtained in some cases, when wells were dug or cleaned, shows a very rapid supply, reaching an estimate in one or two cases of 40,000 gallons in 24 hours. Such a supply is, however, certainly unusual. Ordinarily, as has been stated, owing to the compact nature of the containing material, the inflow is rather slow.

Sanitary Conditions.—One of the most important matters for consideration in connection with the water used by any community is its sanitary condition. Comparatively few people have a proper conception of the means of providing a pure water supply or of the way to retain its purity. Nor do many thoroughly realize what great danger lies in the use of impure water. It is in the hope of directing attention to the great desirability of improvement in the sanitary condition of wells used for domestic purposes that the few words following are put in this report.

The usual sources of water supplies for household purposes are geological in their nature and depend largely for their permanence and purity upon the geological structure of the region. In this state almost the entire supply of water for domestic use is derived from open wells about three feet in diameter and varying in depth, as may be seen from the tables at the end of this paper, from 20 to 50 feet. The water is usually found in a sand and gravel stratum confined by impervious beds of clay, the lower of which generally forms the bed of the common subterranean water supply of this state. A water supply derived from a source thus protected by nature is nevertheless liable to become a source of extreme danger to health unless more than common care is exercised in the location and construction of the well.

A large per cent of the wells visited by the writer were found to be in a dangerous location. For convenience in supplying water to cattle many are in stables or in or near the edge of a stock yard; others are on low ground or on some hillside where the drainage from above tends to soak into the well. Under such conditions it

is the greatest wonder that cases of fever and other diseases are not of more frequent occurrence.

In the country there is no necessity for placing a well in such a position that there will be danger from surface contamination. There is an abundance of room and water is easily obtained almost any where. Special precautions should be used to make tight the top and sides of the well so that the water will filter through as great a thickness as possible before finding its way into the well. This can be secured by laying a brick or stone wall in hydraulic cement from near the bottom of the well to about a foot above the surface. Special care should be taken to see that any open space between the sides of the well and the brick wall is filled at the bottom with cement and sand and clay, and that it is carefully covered at the top with heavy boards and otherwise made tight. Apparent cleanliness and purity should not be assumed to guarantee absolute freedom from contamination.

The location and surroundings of a well must always be looked after. Very frequently disease germs lurk unsuspected in what is to the eye the clearest and purest water. The writer regrets that he cannot here give a large number of analyses to show the organic matter in water from wells of different locations. But it has been almost impossible, considering the conditions under which the work was carried on, to make the organic determinations, even in those waters which were given an approximate mineral analysis, since search for organic matter must be made very promptly after the collection of the sample, which was impossible in these cases. However, the mineral analyses were made and careful observations were taken regarding the location, elevation and various surrounding conditions, and the effects of these conditions may be seen in a way by reference to the table of a few of the analyses made. It will be noticed from these analyses and from the records of field tests that in a very large proportion of cases the water obtained from wells located on low land is poorer than that from those on high land. In most cases where there had been sickness possibly caused by water, the wells used were located in low places or near stables or cesspools.

The number of wells located near barnyards and supplying water for household purposes was astonishing. Were it not for the remarkably healthful climate, the out-of-door occupation and good resisting power of those habitually using such water there would be a large amount of sickness. Water obtained from wells located in low places and where the water rests in blue clay was found nearly always to be stronger in alkalies, salts and suphuretted hydrogen or soluble sulphides and inferior in quality to that from wells located on higher sand and gravel ridges. Very few of the wells of this state are walled up with brick or stone. Wooden planks are generally used simply to keep the well from caving in. Some are not even planked up. The top is usually very poorly covered and many are kept quite open. The best water was found to be from wells from which a large quantity of water was taken.

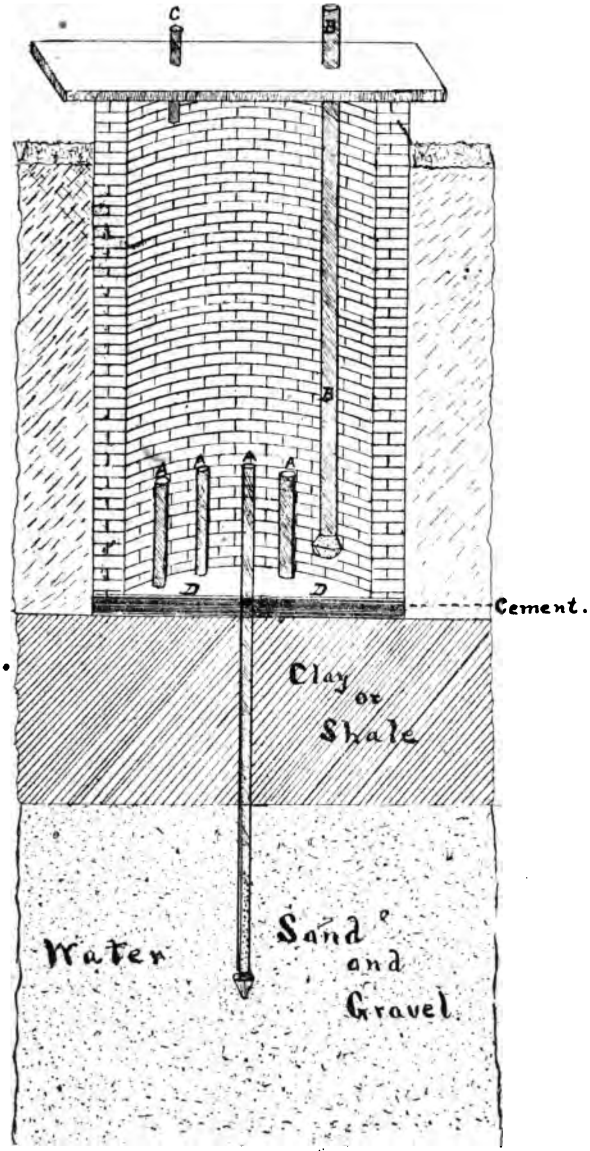
From what has been said it must not be understood that the water of this state is naturally dangerous, for that it not the case. There is, however, much room for improvement in sanitary conditions within the control of man. The following points are suggested as possible aids in bringing about an improvement in the quality of well water used for household purposes in this state. Locate the well on high land, and whenever it can readily be done let it be on a sand and gravel ridge, or at least one which there is reason to believe is underlain with such material. This will not be very difficult to do in the case of most wells in the state.

Investigation goes to show beyond doubt that in most cases the best water is obtained when the well is put through much sand and gravel at least for a portion of its depth. This fact is, of course, generally recognized. Sand and gravel acts as a filtering bed and is often used for the improvement of otherwise impure supplies. Many cities use sand filtering beds with remarkably good results. In the east one of the most thoroughly tested systems of this kind is the comparatively simple sand bed arrangement of the Lawrence, Mass., system by which the water is purified for the domestic use of the city. In this state at Grand Forks a similar system is used with most gratifying results. Usually the organic impurity in the water after filtration amounts to but a small fraction of that found in the unfiltered water. Wherever water is gotten which passes through sand and gravel ridges or layers of this material, as is commonly the case in this part of the state, it will have been subjected to a natural filtration which, as the analyses given in this report show, results in a marked improvement in the quality.

Wells should be located on high lands to prevent contamination from the slow percolation of impure surface water. Wells located in low places are naturally situated to receive the sewage and general drainage from the higher portions of land. High and rolling land favors a "run off" of surface water and so usually prevents the introduction of surface impurities.

For obvious reasons it is imperitive that wells used to supply drinking water should be located at a considerable distance from stables, cesspools, coulees and other sources of contamination. The excavation should not be stopped at too shallow a depth. Many wells were found which were little more than mere basins dug a few feet into the soil and subsoil. The water thus obtained is all from the immediate surface and is very liable to contamination. If possible the water should be gotten from sand and gravel below a layer of compact clay or shale. In this state there is little difficulty in securing such conditions. Wells dug for domestic use should be walled up with brick or stone and *not* with wood, since the latter does not keep out surface water but furnishes favorable conditions for the accumulation and growth of organic matter. It soon begins to decay, thus supplying impurities, while the cracks and rotten places in the wood allow the access of small animals and other means of contamination.

Based upon the principles mentioned, there are many ways of constructing wells which will furnish pure water and be entirely satisfactory. The accompanying illustration is given as a suggestion



A plan for a well for domestic use.

of one safe method of construction adapted to the conditions of the state. The well is dug to within a few feet of the sand which contains the water and which is capped by compact clay or shale. Through this clay or shale the iron tubes "A" are driven, or, if the shale is too hard, the tubes are placed in holes drilled through. All of these tubes "A," six or eight or more in number, pass into the water-bearing sand as seen by the central tube. These tubes are provided with an ordinary pointed cap for the lower end and are perforated along the sides for some distance. The bottom of the well is then cemented very carefully around the pipes and the entire bottom "D" with Portland cement, or with good hydraulic cement, for a thickness of about one foot. Upon this the brick wall is laid in hydraulic cement mortar to about one foot above the surface, and is provided with a well fitting cover. The tube "C" is placed in the cover to allow a free circulation of air. It should be provided with a fine screen on top or a perforated cap and sides. The tube "B" ending in a perforated cap is the suction tube leading to the pump.

A well constructed in this manner is a great improvement over the one of common construction, since it permits no foreign matter to get into the well and does not require the water to stand in the blue clay or shale, which fact will doubtless materially lessen the amount of alkalies as well as of other mineral matter. Whenever it is desired to clean the well the top of the tube "A" can be plugged and the well cleaned very thoroughly. Of course such care and expense need not be taken with wells for stock or irrigation but simply with those which are used for household purposes.

In wells used for domestic purposes it is highly desirable that a large amount of water be removed, for this is an important aid in keeping the supply pure and in preventing the accumulation of alkalies and other salts. In nearly all cases in this state the greater the quantity of water drawn the better its quality. Where windmills are used and a large amount of water is pumped out the improvement is noticeable. The value derived from the removal of a large quantity of water is probably due not only to the prevention of the accumulation of alkalies and other salts derived from the water standing in the surrounding blue clay or shale, but also to the prevention of certain chemical changes which soon take place in the standing water. One of the most noticeable of these is between the alkaline carbonates and sulphides, mostly of iron, which in the presence of a small amount of organic matter probably combine so as to form traces of carbonate of iron and set free a small amount of hydrogen sulphide which gives the offensive odor to many wells in which water is allowed to stand, especially if it be confined in shale. When large quantities are used so that the supply is constantly changed, there is little opportunity for such chemical decomposition.

By the proper construction of the wells and the removal of large quantities of water there is little doubt but what the quality will gradually be much improved. The containing clays and shales will

doubtless be slowly relieved, by the process of washing, of much of their impurities, such as alkalies and other salts.

It is to be desired that in this state more care should be given to the sanitary condition of drinking water. Few subjects need more attention and are worthy of more thought than this one of domestic water supply. Upon it to a great extent depends the health, comfort and prosperity of the whole community.

TABLE SHOWING SALTS AND MINERAL MATTER IN WATER OF WELLS AT DIFFERENT ELEVATIONS IN THE CENTRAL PART OF THE STATE.

Number and Name		1—Willox, north of Leeds	2—Lindeberger	3—Phil. Cocking	4—Goldberg	5—L. A. Johnson	6—F. Wood	7—W. Talgeson	8—C. E. Enger	9—Maristeau	10—Jacobson
Location		Good High	Good Very High	Good Very High	High	Too Near Stock Yard High	Medium	Medium	Medium	In Barn Low	Near Barn Low
Chlorine—Estimated as equivalent to sodium chloride	Grains per gallon	0.49	1.32	0.49	4.12	5.44	3.63	4.12	4 61	9 39	14.67
Hardness—Equivalent to carbonates and sulphates of lime and magnesia	Grains per gallon	18.0	19.0	17.0	44.0	23.0	21.0	7.5	54.5	42.0	79.0
*Carbonates of lime and magnesia and alkalies estimated as equivalent to sodium carbonate	Grains per gallon	4 24	6.36	8.48	4.24	29.68	12.72	25.44	19.08	6.36	23.32
Total solids	Grains per gallon	....	37.9	87.8	78.3	98.9	40.3	81.2	149.6	117.	231.

*With the true alkalies was estimated all or a part of the carbonates of lime and magnesia.

PARTIAL ANALYSES FOR MINERAL SALTS IN WELL WATER AND OTHER WATERS.

Description		11—Sheyenne River	12—Manvaise Coulee	13—Devils Lake	14—Heart River. Dickinson	15—Well at Dickinson	16—J. H. Thornton, east of Carrington	17—Preston Garland, well near Carrington	18—John Neutze, east of New Rockford	19—Andrew Gresser, near Minnewaukan, (over 500 ft. deep	20—Baker well near Oberon
Chlorine estimated as sodium chloride	Grains per gallon	1.65	1.81	79.6	0.83	1.0	1.65	2.8	1.8	111.9	23.9
Hardness equivalent to carbonates and sulphates of lime and magnesia		15.0	17.5	227.5	20.3	23.7	8.5	16.0	15.5	13.0	130.0
All alkaline ingredients including some carbonates of lime and magnesia—Estimated as equivalent to sodium carbonate		29.68	....	19.08	44.5	6.4	12.7	23.3	10.6	12.72	10.6
Total solid residue		58.5	62.3	635.9	127.5	59.0	27 0	58.5	37.5	161.7	466.6

PARTIAL ANALYSES FOR MINERAL SALTS IN WELL WATER AND OTHER WATERS.

Description		21—Fort Totten, spring water from reservoir	22—Cooperstown, city well	23—Zimmerman, near Cooperstown	24—J. T. Cooper, near Cooperstown	25—E. P. Wells, north of Jamestown	26—John Rathe, near Fingal	27—Well near Crystal	28—Tollef Tollefson, near Churchs Ferry	29—Patterson, west of Portland	30—Guyther well
Chlorine estimated as sodium chloride	Grains per gallon	0.8	29.7	3.5	1 5	3.8	....	0.66	67.07	10.6	13.2
Hardness equivalent to carbonates and sulphates of lime and magnesia		28.0	79.1	300.0	19.5	9.0	15.0	36.4	560	27.6	4.8
All alkaline ingredients including some carbonates of lime and magnesia—Estimated as equivalent to sodium carbonate		10.6	6.4	29.7	25.4	16 96	12.7	....	10.6	8.5	48.8
Total solid residue		40.0	130.7	658.0	68.0	57.4	40 5	40.6	993 2	61.5	109.2

PARTIAL ANALYSES FOR MINERAL SALTS IN ARTESIAN WATERS.

Description		31—Devils Lake	32—Wimbledon (R. R.)	33—Conway	34—Blanchard	35—Burke's well, Blanchard	36—Jonas Berg, Cummings	37—Cummings	38—Ellertson, Mayville	39—McUlland, east of Mayville	40—Park well, Mayville
Chlorine estimated as sodium chloride	Grains per gallon	107.4	80.42	219 18	95 37	104.9	77.0	157.9	90.75	74 08	93.56
Hardness equivalent to carbonates and sulphates of lime and magnesia		3.2	105.0	15.0	11 5	14.0	32 6	36.8	37.0	36 0	50.7
All alkaline ingredients including some carbonates of lime and magnesia—Estimated as equivalent to sodium carbonate		61 5	6.36	31.8	14.8	12.7	12.7	4.3	8.5	8.5	6.4
Total solid residue		357.5	117 0	326.9	245.2	261.0	241.5	321.2	249.3	242 0	263.5

PARTIAL ANALYSES FOR MINERAL SALTS IN ARTESIAN WATERS.

Description		41—Portland, city well	42—Well near Grand Forks	43—Moorhead city well	44—McPhedran, near Tower City	45—Tower City well	46—Talcott, near Tower City	47—Capt. May, Casselton	48—Old city well, Casselton	49—J. R. Smith, near Wheatland	50—Butkkee, near Wheatland
Chlorine estimated as equivalent to sodium chloride	Grains per gallon	96.03	78.52	11.88	2.8	129.0	1.3	57.58	57.75	67 8	50.8
Hardness equivalent to carbonates and sulphates of lime and magnesia		44.0	25.4	17.0	22 0	7.6	32.6	3.0	2.2	7.0	39.0
All alkaline ingredients including some carbonates of lime and magnesia—Estimated as equivalent to sodium carbonate		6.4	--------	17.0	17.0	23.3	21 2	25 4	23.3	25.4	4.2
Total solid residue		273.0	114 2	59.0	69.9	230.5	78.6	212.0	197.8	221.0	156.8

SANITARY ANALYSES OF WATER.

Description		51—Artesian well at Hillsboro	52—Goose River water	53—Kingman Ridge well, near Hillsboro	54—Artesian well near Grand Forks	55—Grand Forks city water, filtered	56—Larimore city water	57—Well water near Crystal	58—A well at Michigan	59—City well at Minot	60—Mouse River
Free ammonia	Parts per million	1.0314	1.306	0.026	1.60	0.054	none	0.46	0.12	0.052	0.5
Albumenoid ammonia	Parts per million	0.089	0.121	0 14	none	0 19	0.02	0.106	2.0	0 11	1.0
Chlorine.					potassium chloride 29.8						
Chlorine estimated as sodium chloride	Grains per gallon	95.86	36.3	1.98	235 4	0.49	1 26	0.76	7.27	1.65	0.29
Total hardness	Grains per gallon	57.5	51.0	23.0	156.2	14.1	15.8	36.4	32.0	28.0	30.0
Total solid residue	Grains per gallon	191.2	125.72	34.0	432.2	21.8	21.5	40.6	190.0	43.4	86.3

INDEX TO ILLUSTRATIONS